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PACE

Pathway to a Competitive European Fuel Cell micro-CHP Market

REPORT

D 3.6 – Briefing Papers Linking Micro-CHP with EU & National Climate and Energy Strategies

Policy Recommendations for favourable legislation in the EU, Belgium, Germany, Italy, the Netherlands and the United Kingdom

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Briefing Papers Linking Micro-CHP with National Climate and Energy Plans

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1. Introduction

Europe has embarked on an ambitious decarbonisation journey, accelerating efforts to scale up renewable energy and energy efficiency uptake by 2030, on the path to reaching net-zero emissions by 2050. The recent economic and geopolitical context, including the COVID pandemic and the war in Ukraine, has also exacerbated EU's vulnerabilities relating to enegry security and affordability. The buildings sector has been indentified as key in Europe's decarbonisation and clean energy objectives. Fuel cell micro-CHP (FC micro-CHP) is one of the clean energy solutions for buildings, which can positively contribute towards decarbonisation, energy savings and consumer empowerment.

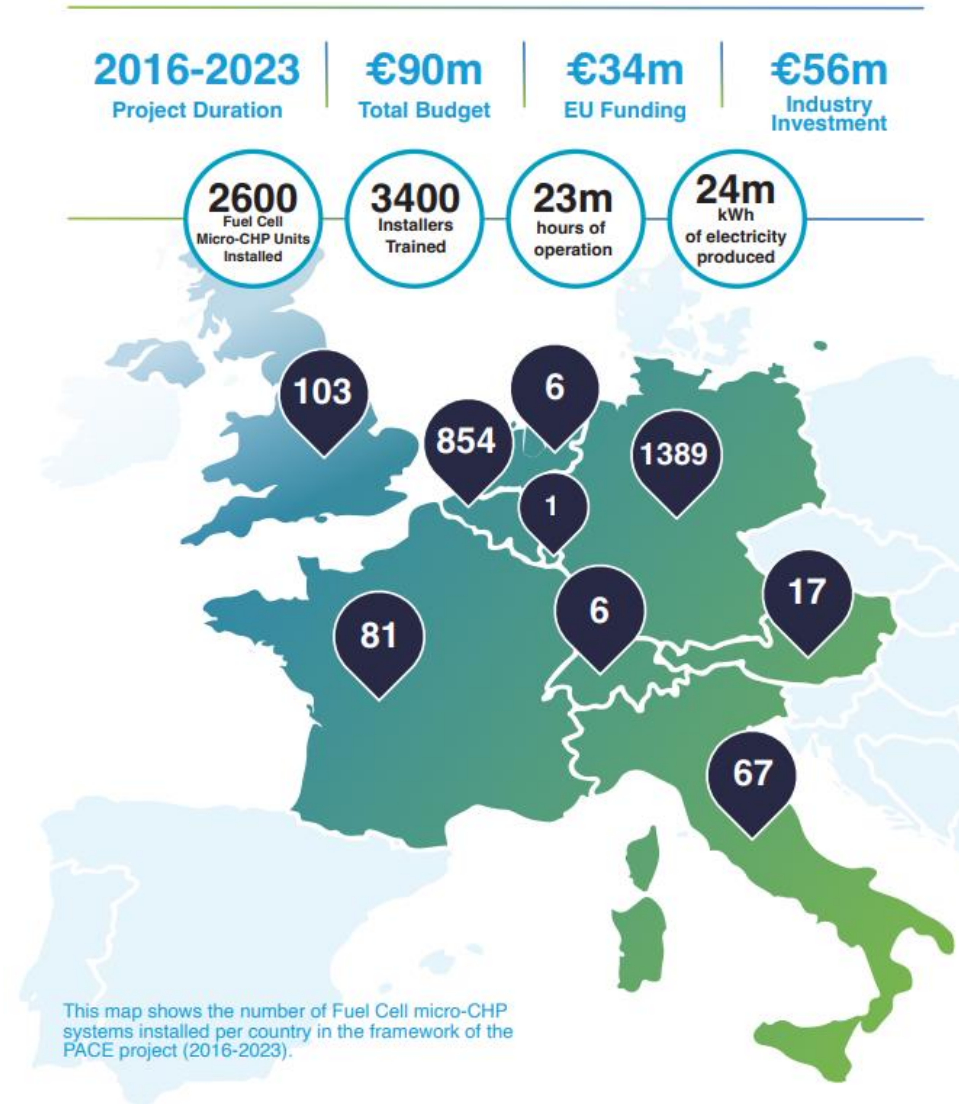
This report aims to link micro-CHP benefits with the climate and energy objectives at EU level and in key European countries – Belgium, Germany, Italy, the Netherlands and the United Kingdom. It includes a collection of detailed briefing papers assessing contribution that FC micro-CHP can have towards the target countries overall energy, climate and competitiveness agendas. The papers take a 2030 perspective as a milestone to a net zero carbon economy by 2050, using the EU Green Deal, Fit for 55 and REPowerEU policy frameworks as a basis. This work draws on PACE project results and makes recommendations for favourable fuel cell micro-CHP policies, in the context of the broader climate and energy strategies at national levels.

Fuel Cell micro-CHP is a mature technology that is already available and in operation globally. It is highly efficient, as both electricity and heat are produced in the same building where they are being used, thereby minimising energy losses and cutting energy costs. It reduces the strain on electricity grids by generating power locally, complementing demand electrification and intermittent renewable energy sources such as wind turbines and solar panels.

THE PRESENT PAPER CONCLUDES THAT SCALING UP FC MICRO-CHP ADOPTION ACROSS MANY EUROPEAN COUNTRIES CAN PLAY AN IMPORTANT ROLE IN INCREASING ENERGY EFFICIENCY, DECARBONISING THE BUILDING SECTOR AND SUPPORTING POWER SYSTEM RESILIENCY, ALL WHILE EMPOWERING ENERGY CONSUMERS.

2. PACE Project and its achievements

EU flagship PACE is a major initiative aimed at ensuring the European FC micro-CHP sector makes the next move to mass market commercialisation. Between 2016-2023, the project **has deployed more than 2.600** new fuel cell micro-CHP units with real customers and monitor them for an extended period.

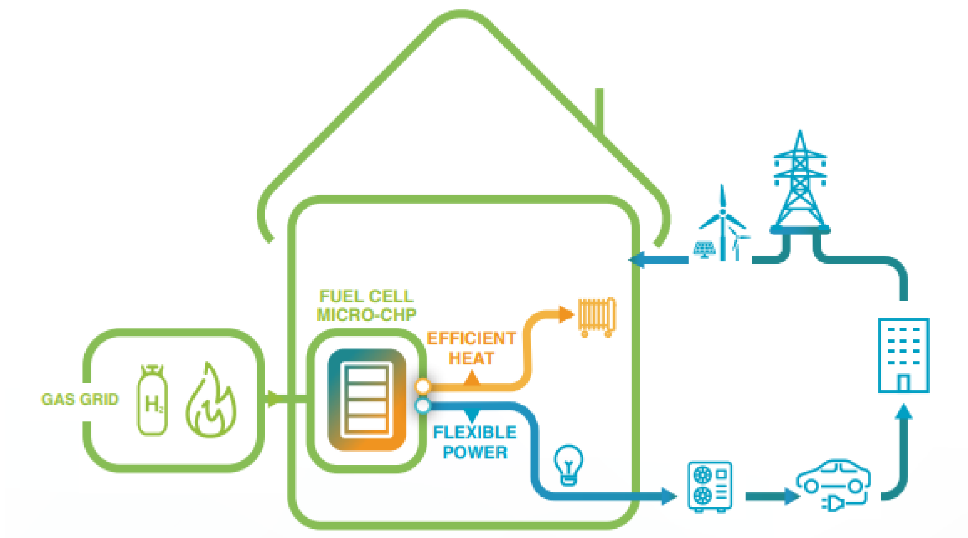


PACE project has provided an evidence base to showcase how FC micro-CHP solutions can contribute towards EU and national climate, energy and net-zero industry competitiveness objectives.

3. What is Fuel Cell micro-CHP?

Fuel Cell micro-Cogeneration (also called Fuel Cell micro-CHP, where CHP stands for Combined Heat and Power) is a highly efficient energy solution that can be installed in buildings of various sizes and uses. It produces electricity for self-consumption or grid feed-in, as well as heat to cover the building's heating, hot water and potentially cooling demand.

At the heart of the system is a Fuel Cell, where hydrogen is combined with oxygen in a clean and very efficient process that generates both electricity and heat. The only by-product of this electrochemical process is water (H2O). No chemical pollutants or particulate matter are produced.



The PACE field trial installed a range of different products by major EU manufacturers, using two main types of fuel cells: proton-exchange membrane fuel cell (PEM) and solid oxide fuel cell (SOFC). PEM and SOFC technologies can be installed in different buildings, depending on the specific energy demand profile of the customer.

4. Fuel cell micro-CHP in the context of Europe's Energy & Climate Objectives

In December 2019, the European Commission presented the European Green Deal, a growth strategy to transition the EU economy to a sustainable economic model. The overarching objectives of the **EU Green Deal** are to reduce greenhouse gas emissions in Europe by 55% by 2030 and for the EU to become the first climate neutral continent by 2050, resulting in a cleaner environment, more affordable energy, new jobs and better overall quality of life.

The **Fitfor55 package**, proposed in 2021, and the **REPowerEU initiative**, adopted in 2022 in reaction to the war n Ukraine, have set higher ambition for the EU and its Member States on energy and climate objectives. **Higher targets for 2030 on energy efficiency, renewable energy and emission reductions are to be delivered through the faster deployment of clean energy technologies.**

In the context of increased decarbonisation ambition, buildings are prioritised as a key sector for the deployment of low carbon, efficient and renewable energy solutions. The ongoing **revision of the Energy Performance of Buildings Directive**, launched in December 2021 by the European Commission, aims to accelerate the renovation of buildings and aim for all of EU's buildings to become zero-emission buildings by 2050.

Given the recent energy price crisis, which Europe has experienced since mid 2021, European institutions and national governments have also had to react to **Europe's vulerabilities in terms of energy security and affordability**. The **Electricity Market Reform proposals**, published by the European Commission in March 2023, as well as the UK's ongoing revision of Electricity Market Arrangements, highlight the increasing need for energy system integration and flexibility, to esnure that **decarbonisation is achieved at the lowest cost for consumers, while maintaining highest level of resiliency**.

As highlighted in the **EU Net-zero Industry Act proposal,** published by the European Commission in March 2023, EU's increased demand for clean energy solutions shall be met as a priority via net-zero technologies produced in Europe.

FUEL CELL MICRO-CHP SOLUTIONS ARE UNIQUELY PLACED TO CONTRIBUTE TOWARDS EU'S CLIMATE AND ENEGRY OBJECTIVES, AS WELL AS HELP BOOST NET-ZERO INDUSTRY AMBITIONS.

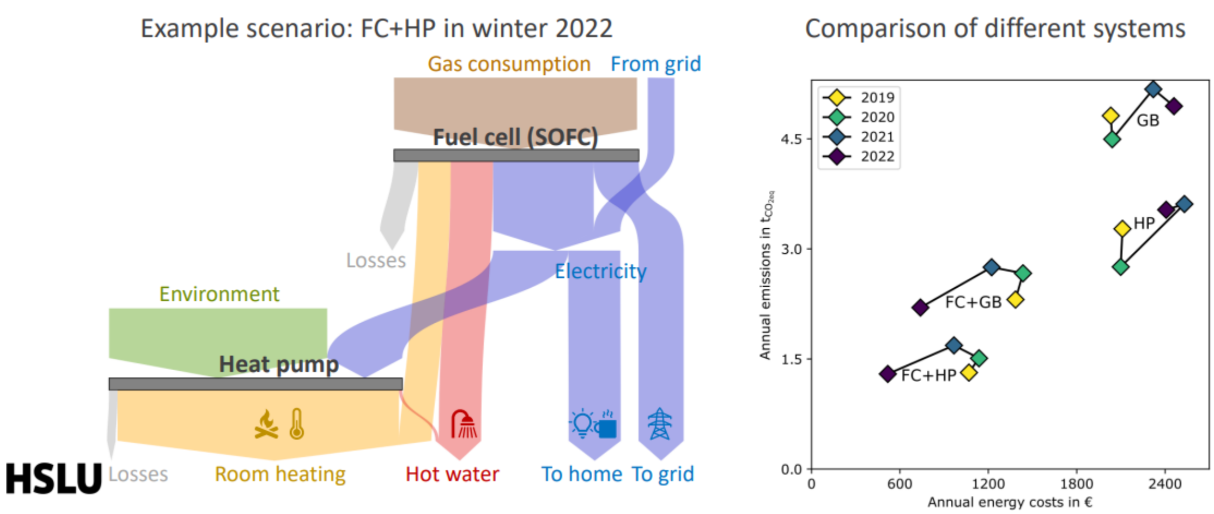
5. Fuel cell micro-CHP Benefits in the Context of Europe's Energy & Climate Objectives

Given the European and national policy context, fuel cell micro-CHP can contribute significnatly towards EU's energy, climate and competitiveness ambitions, as outlined in the summary below. Detailed country-level evidence and policy recommendations are provided under in Chapter 7 for Belgium, Italy, the Netherlands, Germany and the UK.

- ✓ **Energy efficiency:** FC micro-CHP have total efficiency above 95% and electrical efficiencies between 35% and 60%, depending on the fuel cell technology employed. Fuel cell micro-CHPs reduce primary energy consumption by ~30% compared to a condensing gas boiler and electricity from the grid.

✓ **Decarbonisation:** Even when running on natural gas, energy savings achieved by FC micro-CHP translate into significant emission reductions compared to a gas boiler and the marginal electricity mix displaced from the grid. Emission reductions are higher in countries with more carbon intensive power systems. Further emission reductions and net-zero direct emissions are achievable through the switch to renewable gases and hydrogen.

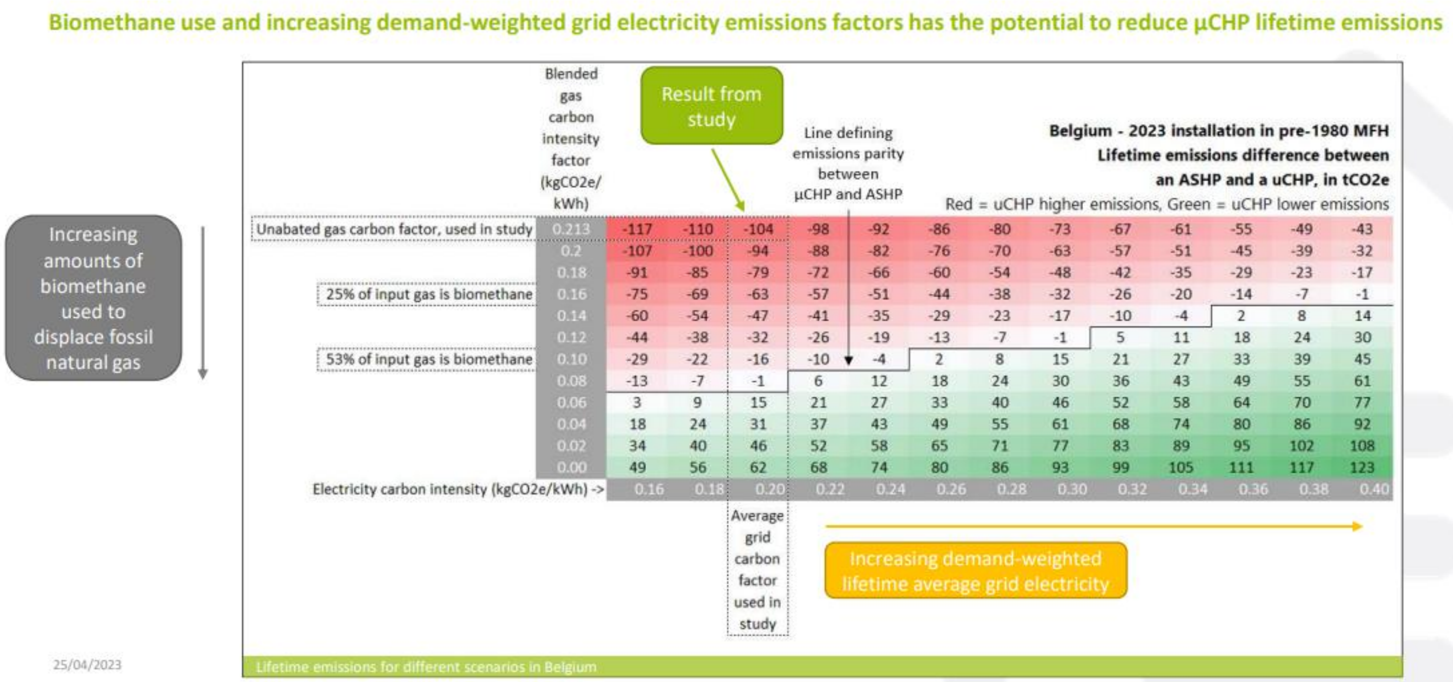
A PACE analysis comparing different heating systems' CO2 emissions in an average home in Germany between 2019-2022, shows that installing a stand-alone fuel cell micro-CHP (FC) or a fuel cell in combination with a heat pump (HP), significantly reduces CO2 emissions compared to a standard gas condensing boiler (GB).



Source: PACE (HSLU), April 2023

In the long term, the emission reductions potential of fuel cell micro-CHP depends on the relative increase in renewable energy uptake in gas versus electricity grids. Fuel cells will be key to ensure the efficient uptake of renewable gases and hydrogen in buildings, in those countries where these fuels will be made available and affordable in the residential sector.

The sensitivity analysis below carried out for Belgium, shows scenarios under which fuel cell micro-CHP running on biomethane could represent a good alternative to space heating electrification.



	Blended gas carbon intensity factor (kgCO2e/kWh)													
Unabated gas carbon factor, used in study	0.213	-117	-110	-104	-98	-92	-86	-80	-73	-67	-61	-55	-49	-43
	0.2	-107	-100	-94	-88	-82	-76	-70	-63	-57	-51	-45	-39	-32
	0.18	-91	-85	-79	-72	-66	-60	-54	-48	-42	-35	-29	-23	-17
25% of input gas is biomethane	0.16	-75	-69	-63	-57	-51	-44	-38	-32	-26	-20	-14	-7	-1
	0.14	-60	-54	-47	-41	-35	-29	-23	-17	-10	-4	2	8	14
	0.12	-44	-38	-32	-26	-19	-13	-7	-1	5	11	18	24	30
53% of input gas is biomethane	0.10	-29	-22	-16	-10	-4	2	8	15	21	27	33	39	45
	0.08	-13	-7	-1	6	12	18	24	30	36	43	49	55	61
	0.06	3	9	15	21	27	33	40	46	52	58	64	70	77
	0.04	18	24	31	37	43	49	55	61	68	74	80	86	92
	0.02	34	40	46	52	58	65	71	77	83	89	95	102	108
	0.00	49	56	62	68	74	80	86	93	99	105	111	117	123
Electricity carbon intensity (kgCO2e/kWh) ->		0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40

Source: PACE (Element Energy), April 2023

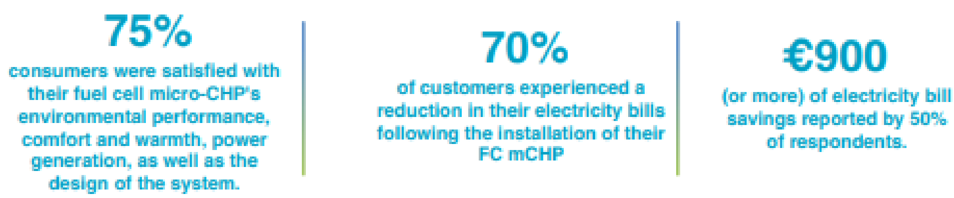
- ✓ **Clean air:** Fuel cells produce heat and power through an electrochemical process, without combustion. This helps avoid local air pollution occurring when heating buildings or in power production.

- ✓ **Renewable energy integration:** Fuel cell systems are renewables-ready, ensuring the most efficient way to use valuable fuels such as renewable hydrogen or biomethane as they become available to consumers.

- ✓ **Energy system resiliency:** Fuel cells produce dispatchable electricity locally, displacing less efficient and more polluting centralized power plants used to balance the electricity system at times of insufficient PV and wind power. Fuel cells will increasingly complement direct electrification via heat pumps and EVs, reducing strain on power grids during times of peak demand.

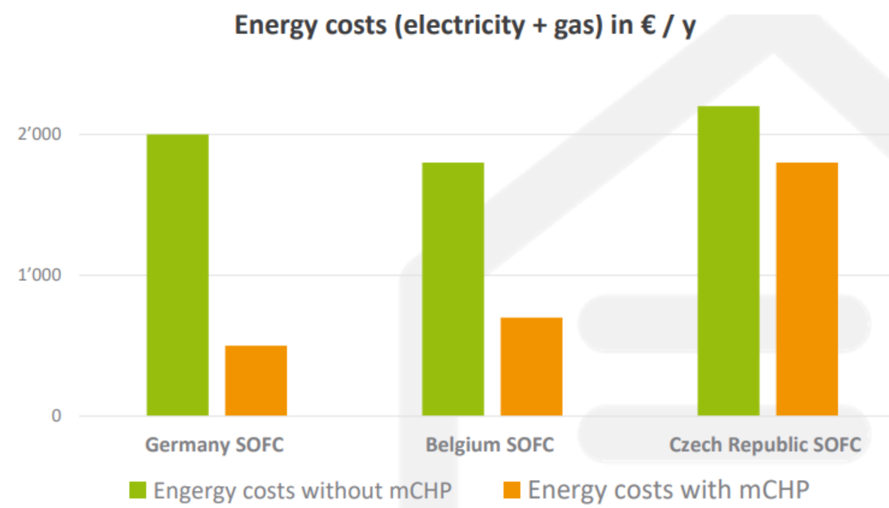
- ✓ **Empowered consumers:** Fuel cell users are empowered to save energy, reduce their energy bills and produce their own heat and power when they need it. Fuel cells can be combined with other clean buildings solutions, such as heat pumps, PVs or EVs, to further increase environmental benefits and cost reductions.

A survey of more than 1700 Fuel Cell micro-CHP system owners carried out in the framework of the PACE project found that there was a high level of satisfaction with the technology.



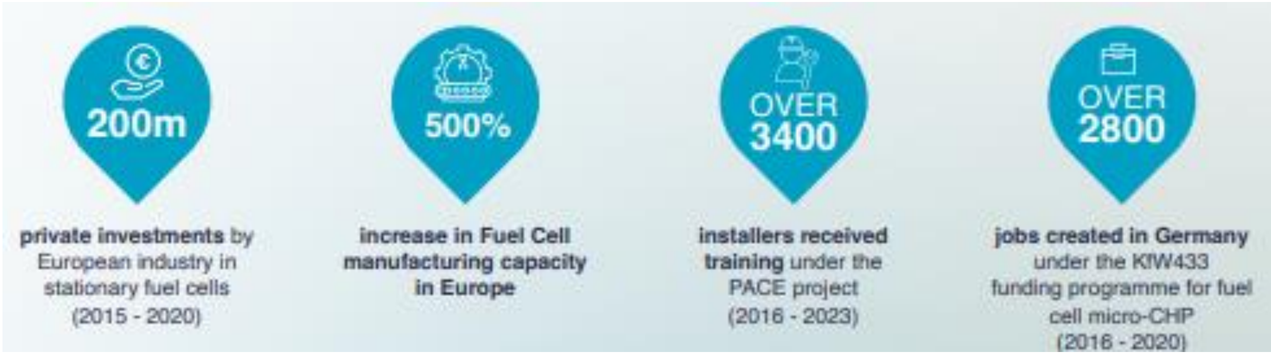
Source: PACE (Element Energy), April 2023

PACE modelling has demonstrated that high savings in annual energy costs are observed in Germany and Belgium due to self-consumption, when 2021-2022 are taken as reference years.



Source: PACE (HSLU), April 2023

- ✓ **European industrial net-zero leadership:** The development, design and manufacture of Fuel Cell micro-CHP systems and their components provides an important source of high-quality jobs and contributes to Europe's economic prosperity



6. Overview of Fuel Cell micro-CHP Benefits in Target Countries and Recommendations

Fuel cell micro-CHP benefits will vary depending on the national contexts and factors such as the marginal power mix, strategies for the adoption of renewable and decarbonised gases, hydrogen strategy, market price developments (i.e. clean spark spread between electricity and gas prices).

Below is an summary of how fuel cell micro-CHP links to the energy and climate objectives of the target countries considered. This overview is based on the detailed assessments carried out in the country briefing papers presented in Section 7.

Country	Energy Efficiency	Decarbonisation	Clean Air	Energy systems resiliency, Adequacy & Flexibility	Customer empowerment/ Lower cost
Belgium					
Germany					
Italy					
Netherlands					
United Kingdom					

7. Briefing Papers Linking Micro-CHP to National Strategies and Objectives

7.1 PACE Policy Analysis and Recommendations on fuel cell micro-cogeneration in Belgium

Representing the Fuel Cell micro-Cogeneration (FC micro-CHP) sector, the PACE project welcomes Belgium's strategies and plans to achieve net zero by 2050 according to the European Union's strategy and initiatives under the European Green Deal. Moreover, the regions in Belgium - Flemish, Walloon and Brussels Metropolitan, have become almost exclusively competent for environmental matters, including granting environmental permits and ensuring permit compliance, but together with the Belgian Federal Government, they have shown their strong commitment to a green and sustainable economic recovery.

Fuel Cell micro-Cogeneration is a highly efficient approach to providing on-site electricity and heat suitable for a small business or house from a single fuel. First, the fuel is transformed into hydrogen and the fuel cell uses this hydrogen to generate electricity and heat. Fuel Cell micro-Cogeneration units are designed to meet the electrical, space heating and hot water demands of a building. More information on PACE Project can be found *HERE*.

This briefing paper makes policy recommendations to support the widespread deployment of fuel cell micro-cogeneration systems, while providing a review of policy frameworks for the four identified and prioritised targeted countries expected to impact the uptake of the technology in the coming decade. This paper highlights the benefits of fuel cell micro-cogeneration in relation to Belgium's energy and climate objectives to achieve net zero economy by 2050.

With a technical potential for fuel cell micro-CHP technologies in Belgium assessed by COGEN Flanders at 200,000 units by 2030, **Belgium should not miss the opportunity of reaping the benefits from the large-scale deployment of these products.** However, for a successful FC micro-CHP market entry, industry efforts need to be complemented by high level political commitment. Given the ambitious target in decarbonising the energy, reducing carbon emissions and improving the efficiency of the energy system can be effectively achieved due to wide deployment of micro-CHP. According to the study done by the ene.field EU project on "*Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System*", the magnitude of the carbon saving per kW installed micro-CHP in Europe is estimated between 370 – 1100 kg CO2 per year. In the short and medium term, at least when the use of conventional coal/gas/oil-fired plant is still dominant, the impact of micro-CHP in reducing carbon emissions is expected to be relatively significant. In the long term, when the supply of electricity is mainly from low-carbon generation sources, the use of fuels from sustainable and low-carbon sources will be needed for micro-CHP. The results are shown in Figure 1.

With heat storage	Electric power (MWe)	Electricity production (GWh)	Number of green certificates	Heat production (GWh)
Energy potential	**210.3**	**1 169.7**	**1 730 484**	**1 854.8**
- Commercial	67.4	332.9	208 932	495.1
- Industry	21.8	93.6	57 807	123.0
- Housing	121.2	743.1	1 463 745	1 236.8
Economic Potential - Scen: Stability	**154.6**	**900.2**	**1 546 687**	**1 450.3**
- Commercial	39.0	192.3	117 632	262.5
- Industry	1.8	9.8	6 276	16.0
- Housing	113.8	698.1	1 422 779	1 171.7
Economic Potential - Scen: rise in electricity	**153.2**	**881.2**	**1 516 930**	**1 433.0**
- Commercial	44.6	218.7	135 321	311.2
- Industry	2.9	14.5	9 111	22.7
- Housing	105.6	648.0	1 372 498	1 099.2
Economic Potential - Scen: increase in fuels	**135.8**	**790.3**	**1 441 414**	**1 287.7**
- Commercial	35.5	175.0	106 742	235.0
- Industry	1.2	0.076	4 883	12.6
- Housing	99.1	607.8	1 329 789	1 040.0

Table 25: Extrapolated bottom-up potential of cogeneration in the Brussels-Capital Region

At the individual level, cogeneration is not a credible solution because of its costs and its technical complexity. However, cogeneration is relevant for collective projects for the production of heat and electricity. From a residential point of view, apartment buildings with a large number of households, which create a significant and stable demand for heat, constitute a target audience for cogeneration.

https://energy.ec.europa.eu/system/files/2021-10/be-bru_ca_2020_en.pdf

Vlaanders: From 2021, residential properties in new large developments and large apartment buildings can only be connected to natural gas for collective heating via CHP or in combination with a renewable energy system as the main source of heating.

Seasonal generation -demand mismatches, caused by winter peaks from heat electrification and the variability of solar PV and wind, can also be better managed together with fuel cell deployment. These peaks should be converted and stored in Hydrogen and used in fuel cells during night- and winter time. Energy profiling, Virtual Power Plant and smart grid opportunities can help with grid balancing.

Energy and climate policy framework in Belgium

In October 2020, the European Commission published an assessment for each NECP. Belgian climate and energy policy is a combined effort of the Flemish, Walloon and Brussels Capital regions. A high proportion of Belgians (60 %) expect national governments to tackle climate change. According to the European Parliament analysis on *Climate action in Belgium*, Belgium accounts for 3.3 % of total EU greenhouse gas (GHG) emissions with the energy industries accounted for the largest share of Belgium's

GHG emissions. Moreover, Belgium reached a 9.9 % share of renewable energy sources in 2019. Its ambition to reach its 2030 target of a 17.5 % share focused mainly on wind and photovoltaic energy, biofuels and the use of waste heat. Measures planned to achieve the energy efficiency targets are focused mainly on the building and transport sectors.

Buildings

In addition, under the current legislation, EU Member States have binding annual greenhouse gas emission targets for 2021-2030 for those sectors of the economy that fall outside the scope of the EU Emissions Trading System (EU ETS), known as the Effort Sharing Regulation. The Regulation is based on the principles of fairness, cost-effectiveness and environmental integrity. Belgium is obliged to reduce its emissions by 35 % compared with 2005 levels. The Commission notes a 0.6% gap towards the 2030 target, based on the regional targets (Wallonia -36.8%, Brussels Capital Region -39.4% and Flanders -32.6%) also mentioning that the degrees of detail and robustness of the estimated targets vary significantly between the regions. Belgium's NECP projects a 2030 emissions reduction of 41 % for the building sector compared with 2005. To achieve this reduction the NECP mentions acceleration of the renewal, and phasing out, of fossil fuel boilers, the introduction of a renewed energy performance certificate in buildings, and fiscal measures such as lower registration taxes and cheaper loans.

According to the European Commission, in EU households, heating and hot water alone account for 79% of total final energy use (192.5Mtoe). Approximately 75% of heating and cooling is still generated from fossil fuels while only 22% is generated from renewable energy. Therefore, to achieve all of the objectives above Belgium will need to: 1) rely on a diverse mix of renewable and efficient solutions; 2) promote the efficient use of energy in buildings via heat pumps, cogeneration and district heating; and 3) foster system resiliency and flexibility by supporting the highly efficient and low-carbon dispatchable power solutions, including fuel cell micro-CHP, which can run on increasingly renewable fuels, as renewable gases and hydrogen. Micro-CHP solutions are now available on the market and can be installed in up to 25% of EU's buildings[1], as part of a cost-effective pathway to a carbon neutral EU by 2050. Moreover, electrically led fuel cells can support grid infrastructure and mitigate outages caused by the increased power demands from heat pumps, electric vehicles and other electrification measures. Covering the baseload of housing stock and business operations (continuously) decentralises power consumption. As buildings electrify, demand response, flexible generation and energy efficiency will play an even more important role in integrating higher shares of renewable energy at lowest cost for consumers. From a residential point of view, apartment buildings with a large number of households, which create a significant and stable demand for heat, constitute a target audience for cogeneration.

By 2030, Belgium aims to raise the renewable energy share in electricity (37.4%), transport (23.7%) and heating and cooling (11.3 %). This is to be achieved through investment in wind and photovoltaic energy

[1] *https://www.artelys.com/wp-content/uploads/2020/11/Artelys-Presentation-Key-Findings-Study-Commissioned-by-CE-final-1.pdf*

production, biofuels and the use of waste heat[2]. While it is important to accelerate renewable energy across different sectors, it is equally important to connect those objectives with the energy efficiency first principle. It is noticeable that there is lack of consistency between targets at the federal and regional levels, which may hinder the process of achieving desired outcomes. Therefore, to fully reap the benefits of micro-CHP, Belgium should foster all renewable energy sources and their efficient use for the affordable and secure supply of heat and power to buildings.

Hydrogen

On 29 October 2021, the Belgian Federal Government launched its Hydrogen Vision and Strategy, which aims to turn Belgium into an import and transit hub for clean hydrogen in Europe. The Belgian Strategy assumes that the current demand in Belgium for both hydrogen and its derivatives will reach between 125 and 175 TWh/year by 2050 (including bunkering fuels) and addresses both "renewable" and "low-carbon" hydrogen, where the latter constitutes a transitional fuel[3]. The Federal Government identifies three main sectors in which renewable hydrogen can help achieve carbon neutrality by 2050: industry, transport and flexibility to power grid. The flexibility of hydrogen can be used as a complement to batteries to store excess production from intermittent renewable energy sources and make such energy available at times of shortage. This flexibility to power grid can be also enhanced by fuel cell micro-CHP in residential applications, which helps to reduce CO2 emissions. Flexible solutions to decarbonise heat in buildings, including fuel cells, are hydrogen-ready and can provide 100% renewable energy of green gas in the grid. Fuel Cell technology is designed with this transition in mind and using it will further accelerate future gains in energy efficiency and carbon reduction. Moreover, residential fuel cells have the added benefit of generating electricity when and where needed, addressing the challenges of direct electrification and increasing shares of variable renewable sources. The evidence shows that seasonal generation/demand mismatches, caused by winter peaks from heat electrification and the variability of solar PV and wind, can be better managed together with fuel cell deployment in buildings. In addition, residential fuel cells can support grid infrastructure and mitigate outages caused by the increased power demands from heat pumps, electric vehicles and other electrification measures. Covering the baseload of housing stock and business operations (continuously) decentralises power consumption. Making it local, efficient and flexible.

Support for micro-CHP in Belgium

In Belgium micro-CHP systems are eligible to receive support mechanisms, but their level is determined by each region, which result in uneven recognition of technology among three federal regions – Wallonia, Brussels Capital Region and Flanders.

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[2] *Climate action in Belgium*, European Parliamentary Research Service

[3] *Focus on hydrogen: Belgium announces hydrogen vision and strategy as part of energy transition plan*, Clifford Change

In Flanders, companies, individuals as well as non-commercial institutions and legal entities under public law are eligible for a feed-in premium scheme for micro-CHP up to 10kW, which uses biogas and has been installed after January 1, 2018. The amount of support is determined, among other things, by the electrical power and the fuel type. The maximum premium is calculated according to the formula is 4700.P_nom, where P_nom is the nominal electrical power of the installation.

In Wallonia you are eligible to receive green certificates – support mechanism for renewable energy producers, and the guarantee of purchase of green certificates. Moreover, till 2024, Wallonia has released a budget intended to grant a bonus through DSOs (Distribution Network Managers) to compensate for the prosumer tariff, which came into effect on 1 October 2020. The premium is paid to the self-producing residential customer who has a renewable electricity production facility with a net developable power of less than or equal to 10kW, regardless of the production technology used.

The Brussels-Capital Region supports the installation of micro-CHP systems in the form of green production certificates. Completion of a feasibility study also entitles individuals to an energy bonus. Moreover, you can apply for a subsidy A1 (Energy audit) covering the feasibility study necessary for the installation of a cogeneration system. In the Brussels-Capital Region, cogeneration systems are dimensioned primarily for the demand for heating, but they cannot, at the risk of being oversized, cover all the thermal needs of the building where they are installed. It is therefore necessary to install a back-up boiler which will be able to cover the peaks in thermal power demand (mainly in winter).

Overall, the policy framework for fuel cell micro-CHP in Belgium is not favourable and very limited. It often stressed that many district heating networks do not include cogeneration because this investment is economically unviable due to the low cost of buying back electricity injected into the network. The other possibilities for recovering electricity (supply licence or resale to an aggregator) are too complex to implement for medium-sized projects. On the other hand, to some extend this issue can be resolved by the implementation of energy communities (under revised Renewable Energy Directive), which could promote the development of different forms of energy sharing. It is not recognised as a solution which can be used for renovation of buildings, which constitutes a main priority for Belgium in reducing its CO2 emissions. High-level recognition of the environmental and energy security contribution of fuel cell micro-CHP technologies towards Belgium energy transition is key for the successful mass commercialization of these products. The fuel cell sector is dynamic with scope for technology improvement and evolution. According to the Fuel Cells and Hydrogen Joint Undertaking and its *analysis of renewable hydrogen and end users in Belgium by 2030*, the introduction of 6 140-26 660 micro-CHP units in building is estimated.

Benefits of Fuel Cell micro-Cogeneration

The Fuel Cell micro-Cogeneration can significantly contribute towards the energy and climate objectives to benefit from energy efficiency gains and to deliver higher ambition in terms of both energy efficiency and decarbonisation. In short, we would like to stress the following:

Heating and cooling in buildings shall consider fuel cell micro-CHP as a key solution

With total efficiencies of more than 90%, including electrical efficiencies of up to 60% (for SOFC fuel cells) and up to 38% (for PEM fuel cells), this technology can achieve significant energy savings and CO2 emission reductions. This "fuel flexible" technology will be progressively fuelled by renewable energy sources, such as hydrogen and renewable gas.

The efficient use of hydrogen is promoted via micro-CHP

In the long term, biogas or hydrogen at volume could provide an alternative renewable gas to natural gas, which makes a case for the fuel cell micro-CHP more appealing.

The benefits of fuel cell micro-CHP for power grids should be fully recognised

By generating heat and electricity near the point of consumption, Fuel Cell micro-Cogeneration relieves the stress on the electricity grid during peak demand (e.g. for powering heat pumps and charging electric vehicles). They play an important role in generating high efficiency electricity at times of insufficient intermittent renewables. This will also help supply flexible electricity to support the grids and reduce the overall cost of decarbonising buildings.

Empowers consumers

Fuel cell micro-Cogeneration transforms Europeans into active energy 'prosumers' (producer-consumers), creating a decentralised energy system with a reduced carbon footprint and lower energy bills. The most highly efficient fuel cell micro-CHP technologies can be operated according to electricity demand when installed in new low-energy buildings-but are also suitable for existing buildings.

Fosters innovation and high value jobs

Provides new and highly skilled green jobs in Europe, while building on the existing expertise of the heating industry.

Because fuel cell micro-cogeneration attains high efficiencies, it reduces primary energy and results in greenhouse gas (GHG) emission reductions. In addition, the mode of operation of the micro-Cogeneration unit can support the grid integration of variable renewables.

As part of the ene.field EU flagship project, the large scale uptake of micro-CHP has been further analysed in terms of macro-economic and -environmental benefits up to 2050. Comparing two scenarios with or without micro-CHP, installing 1 kW of micro-CHP helps avoid more than 2,000 EUR in the electricity grids (equivalent to **more than EUR 30 bn in avoided grid investments in 2030, assuming the**

full economic potential is realised). Decarbonisation benefits range between 500 kg & 3.5 tons CO2/kW per year between now and 2050, assuming no uptake of renewable gas (which would bring further decarbonisation benefits).

7.1 PACE Policy Analysis and Recommendations on fuel cell micro-cogeneration in Germany

Executive summary

Germany has taken the lead on the energy transition over the last few decades, supporting an ambitious approach to decarbonisation through energy efficiency and renewable energy uptake.

This is complemented by an ambitious push for the industrialisation of clean energy technologies, fostering a strong European manufacturing base for green solutions.

The policy briefing at hand aims to assess how the German energy policy renewed ambitions fare with the objective of extending the country's fuel cell micro combined heat and power fleet (FC mCHP). It does so by disentangling the overarching German energy policy architecture along selected policy dimensions, based on high-level national and European target-setting.

Along these premises, **Chapter 1** enucleates the policy dimensions which will determine the opportunities and the costs for a sustained roll-out of mCHP installations in the next years.

Given the unprecedented energy crisis, security of supply and energy affordability have become critical for the German economy and its citizens. These compounded crises pose a greater dilemma, as their solution must be balanced out with the need to persist with overall system decarbonization.

Against this complex backdrop, **Chapter 2** will provide an overview of the system-wide benefits brought by FC mCHP applications. FC

Chapter 3 will then be dedicated to highlighting how FC mCHP applications are uniquely placed to contribute to Germany's energy, climate, and competitiveness objectives.

Chapter 1: Germany's energy policy framework

Decarbonisation target

Introducing the Climate Action Plan 2050, Climate Action Programme 2030, and Federal Climate Change Act (KSG), Germany has enshrined into national legislation the EU-wide binding target to reduce greenhouse gases emissions (GHGs) by at least 55% in 2030 relative to 1990, as set out in the European Climate Law and to reach net-zero GHGs by 2050. With the amendment of the Climate Action Plan 2050 finalized in 2021, Germany revised upwards EU baseline targets. As a result, the country has committed to becoming greenhouse gas neutral by 2045. It has set the preliminary targets of cutting emissions by at least 65 percent by 2030 compared to 1990 levels, and 88 percent by 2040. As part of its effort to cut emissions, Germany has also underpinned the cumulative 2030 target with sector-specific CO2 reduction targets. Concerning the building sector, the KSG establishes its expected contribution to CO2 reductions, which is estimated to be a saving of 49 million tonnes of CO2-eq by 2030 compared to 2014 levels. Furthermore, the KSG sets caps on emissions from buildings, which cannot exceed 70 million CO2-eq by 2030.
Despite the greater focus on buildings, looking at the projections, the largest share of Germany's efficiency gains will be realized by halving the energy consumption of the industrial sector.

- **RES Penetration in Heating**

The German National Energy and Climate Plan (NECP) published in 2020 described an indicative trajectory to ramp up the share of renewable energies in final energy consumption for heating and cooling. Resulting in an annual increase of 1.3% in accordance with the Renewable Energy Directive II (RED II), Germany had initially targeted a cumulative share of 27% RES in heating and cooling by 2030. The German NECP also established an indicative trajectory for renewable heat in heating networks: by 2030 it should have increased to 30%. The mutated geopolitical context following Russia's invasion of Ukraine, with soaring gas prices and supply instability looming large, has prompted a robust response on the part of the German Government, which has turned its policy priorities toward a massive renewables buildout ahead of time, including in the heating sector. Such a strategic decision came along with several announced legal changes most of which are still under discussion in Parliament at the time of writing. The extent of Germany's energy policy reform will indeed depend on the implementation of the Easter Package and notably the Summer Package, whose focus is on revamping the heating sector through the revision of the Buildings Energy Act (GEG). The latest GEG legislative draft and a recent *work plan*[4] released by the German Ministry for Economic Affairs and Climate Action (BMWK) suggest that the GEG revision expected for Q3 2022 will introduce greater incentives for switching from fossil fuels to renewables in heating.

Among the range of changes proposed, the government demands that all new heating systems introduced after January 2024 must provide 65% of their heating demand from RES whenever

[4]Saving energy for more independence", released by the German Federal Ministry for Economic Affairs and Climate Action on 17 May 2022. The roadmap is available *here*

possible. The obligation is meant to apply to both residential and non-residential buildings and regardless of wheter the installation or the replacement is scheduled. Moreoever, the BMWK's work plan specifies, a distinction will be made according to the purpose of heating systems. Whilst the 65% target will be system-wide for heat generators producing both hot water and heating, systems where hot water and heating run separately will have to comply to the obligation only with respect to the system that is being replaced and reinstalled.

In addition, to stimulate the large-scale deployment of heat pumps, the government intends to amend the funding schemes, ceasing funding for the installation of gas heating systems in new buildings, and only subsidizing the higher EH-55 efficiency standard from next year and EH 40 starting in 2024 for new buildings. A clear indication that Germany intends to fulfill its renewable heating potential is the launch of a *€2.98 billion scheme* to garner investment aid for green district heating based on renewable and waste heat for at least 75%.

With regard to RES gaseous fuels, Germany has set no fixed target for their scale-up in the heating and cooling sector. However, the LTRS acknowledges that debates structured around the "Gas 2030" dialogue process, a stakeholder forum promoted by the Federal Ministry of Economic Affairs and Energy, highlighted wide consensus on the salience of low-carbon efficient heating technologies (including CHP) for the 2030 targets. It also concluded that the implementation of energy efficiency measures in buildings should be accompanied by a system-based design of heating, whereby low-carbon or decarbonised heating solutions including CHP and other supply structures are part of the solution.

Use of Hydrogen in buildings

Germany's policy framework for hydrogen (H2) is outlined by the National Hydrogen Strategy (NHS) adopted in June 2020. Hydrogen is regarded as the key to decarbonizing the high-emitting industrial sector, the strategy recognizing nevertheless that H2 can be a long-term vector to cut down emissions from the heating sector. The document clarifies that even in the event the full efficiency and electrification potentials for process heat generation and buildings are harnessed, gaseous fuel demand will continue in the long term. According to the Federal Government, hydrogen can drive its decarbonization. This is also reflected in a recent inception study[5] on the decarbonisation of heat commissioned to the Fraunhofer ISE and Franuhofer IEE by the German

[5] Fraunhofer ISE, Fraunhofer IEE. (2022) Bottom-up study project on path options for an efficient and socially responsible decarbonisation of the heating sector on behalf of the National Hydrogen Council by Fraunhofer ISE and Fraunhofer IEE, National Hydrogen Council, Fraunhofer Institute for Solary Energy Systems, Fraunhofer Insitute for Energy Economics and Energy System Technology. The inception study is available *here* in German.

National Hydrogen Council, which shows that there is no reliable justification under current knowledge to exclude the option of converting gas distribution networks to hydrogen to use it for the heating of individual buildings in general and for all given individual cases.

The NHS mapped out a host of suggested preliminary measures to accelerate the ramp-up of the hydrogen economy in Germany. Measures 18 and 19 specifically target hydrogen use in buildings. The suggested measures including on hydrogen use in buildings were further assessed in 2021, as part of the 2021 Report on the implementation of the NHS. The main takeaways follow:

- As recommended in the NHS, funding for the Energy Efficiency Incentive Programme for highly efficient fuel-cell heating systems (KfW) was confirmed and further expanded.
- The NHS recommended funding must be directed to hydrogen readiness within the Combined Heat and Power Act (KWKG), set for revision in 2022. The overhaul of the KWKG was finalised with the approval of the "Easter Package", a far-reaching energy policy plan approved in July 2022. As part of the plan, the Renewable Energy Sources Act (EEG) requires new CHP plants to be H2-ready.

Although general enthusiasm persists around hydrogen economics in Germany, the national Long-Term Renovation Strategy (LTRS) released in 2020 as demanded by the Energy Performance Buildings Directive (2018/844/EU) hints that using synthetic hydrogen in buildings should not be a matter of priority until 2030, and its potential for decarbonization should be rather rerouted to address long-lasting hard-to-abate sectors (e.g industry, transport). Nonetheless,

• Energy Efficiency

Within the framework of its Energy Efficiency Strategy 2050 (EffSTRA), Germany has integrated the EU's overall target of reducing primary energy consumption by 32.5% - as of 2030 and relative to the 2007 modelling projections for 2030 - set in the Energy Efficiency Directive (EED). Against this background, Germany has set an efficiency target for 2030 of 30% reduction in primary energy consumption (PEC), relative to 2008. From the Federal Government's perspective, Germany will make the bulk of the effort to realize its energy efficiency potential in the next few years: compared to 2017 levels, the country aims to achieve a 28% reduction in PEC by 2030. This far exceeds the EU-wide target for 2030 relative to 2017, which sits at 18.5%.

The LTRS provides a clearer estimation of the contribution of heating and cooling to the energy efficiency target. As a result, the German contributions to the European targets for energy efficiency in the heating and cooling sector should be decreasing PEC by 30% by 2030 relative to 2008.

- **Adequacy Gap in Germany**

The 2021 European Resource Adequacy Assessment released[6] by ENTSO-E estimates, among other things, the adequacy risks expected for EU Countries in 2025 and 2030, with or without capacity mechanisms (CMs), given the changing structure of power generation capacity. The 2025 reference scenario for Germany does not show considerable adequacy risks due to the low average value for loss of load expectation – the value is a reliability indicator in the electricity market as it represents the expected number of hours per year that a country's electricity production park cannot meet its demand. Despite slightly growing, adequacy risks are minimal also for 2030. Nonetheless, national estimates scenarios considerably vary including in Germany if an economic viability assessment is factored in, which considers capacity exit due to non-viability and potentially decreasing thermal capacity. Under this assumption, adequacy risks appear all around Europe as of 2025, with Germany required to introduce capacity mechanisms to cope with system inadequacy.

Chapter 2: General benefits of micro–CHP Applications

The large-scale deployment of FC mCHP installations goes together with the accomplishment of national and EU-wide climate and energy objectives. Seizing the untapped potential of mCHP installations can contribute to delivering a secure, sustainable and competitive energy transition for European consumers.

- **Decentralization of power and heat supply**

Micro-CHP ensures on-site electricity production and self-consumption, empowering citizens to generate their own efficient, reliable, and affordable clean heat on the spot. For this reason, all CHP users, rely less on electricity drawn from the grid avoiding grid costs such as those related to energy transportation infrastructure both at the end-user and system level. Looking at the numbers, the on-site nature of FC micro-CHP production enables to avoid transmission and distribution grid losses (4%-12%). According to the flagship EU project *ene.field* [7] estimates[8], installing a micro-CHP could reduce power grid costs by 2500 EUR per unit, while helping to reduce peak demand in winter resulting from the installation of heat pumps. Prospectively, researchers from the Imperial College in London have calculated that under a high uptake

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[6] The report is available here: *ERAA | European Resource Adequacy Assessment (ERAA) (entsoe.eu)*

[7] "Ravn Nielsen, ., & Prag, . (2017). *Learning points from demonstration of 1000 fuel cell based micro-CHP units.* Technical University of Denmark. Retrieved from http://enefield.eu/wp-content/uploads/2017/10/ene.field-Summary-Report.pdf

[8] Pudjianto, D. (2017). Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System. Imperial College London. Retrieved from http://enefield.eu/wp-content/uploads/2017/10/WP-5.4-Impact-of-widespread-deployment-of-fuel-cell-mCHP-041017-Final_.pdf

scenario, micro-CHP can save European consumers € 62 billion in avoided grid costs, which is equivalent to 28% of projected additional costs for 2030.

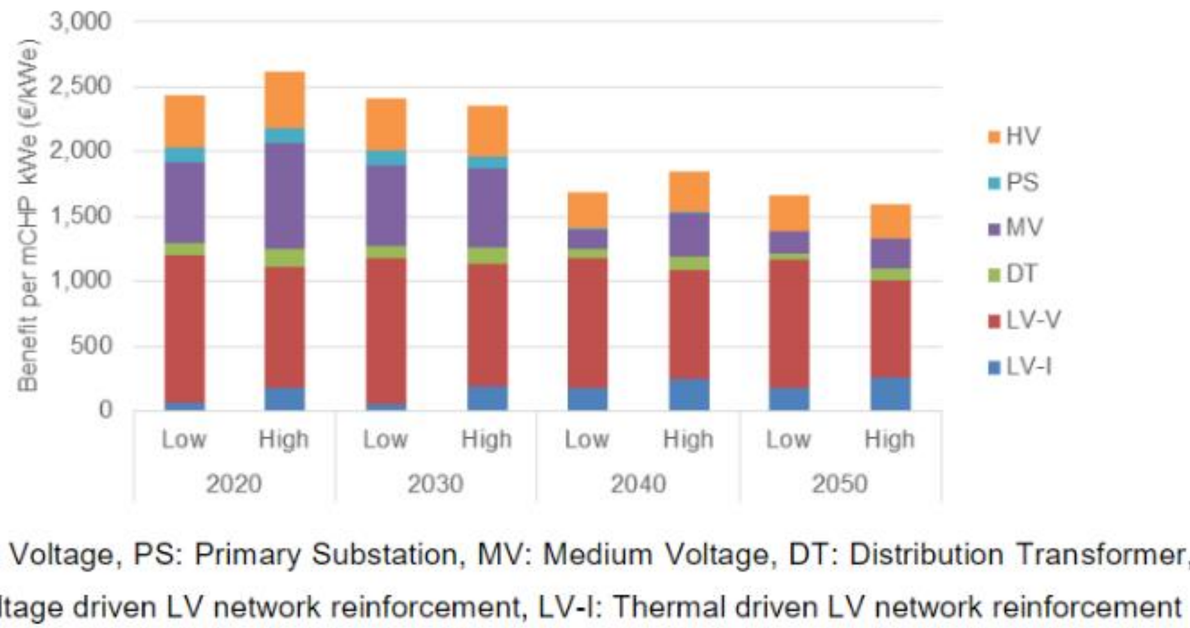


Figure 1 Estimated average value of micro-CHP in reducing distribution network cost in Europe in different scenarios

Alongside reduced user costs, the roll-out of mCHP installations mitigates network overload risks, as both electricity and heat are produced locally.

- **Higher system resiliency supporting the buildout of renewable energy**

Micro-CHP can participate in grid-balancing and help support intermittent generation of electricity from renewables, by quickly ramping up and down electricity production. For example, a micro-CHP unit can efficiently generate electricity at times of need, both tackling peak heat demand periods when higher generation capacity is needed, or the RES generation output fails to meet demand. Among other features, micro-CHP units can also provide a local peaking capacity (back-up) and become an alternative to the conventional boiler in a smart home environment where the electricity and heat demand can be managed more efficiently.

- **Compatibility with smart grids**

The FC micro-CHP technology is well suited for integration into smart grids, enabling to fully harness the benefits of grids digitalization while offering grid-balancing and peak shaving services. In this connection, micro-CHP units can be remotely controlled and can adjust to external heat and power demands at seconds' notice when at operating temperature.

- **Advancement of energy system Integration**

The rollout of micro-CHP units can prove a key system integration solution, linking electricity, heat and gas systems at local level in the most efficient way possible. Micro-CHP applications are well suited to complement the direct electrification of heat, as they help supply heat and power at times of peak heat demand. A 2021 study[9] released by consulting company Artelys shows that synergies between direct electrification (with heat pumps) and efficient indirect electrification (with cogeneration) are key to maintaining system stability and lower overall system costs in a net zero energy system.

- **Decarbonisation and environmental benefits**

In the context of the scaling up of RES-based CHP (running on H2 or other renewable gases), micro-CHP will be increasingly associated with significant emissions reductions or even negative emissions, when coupled with CCUS technologies. As proof of that, LCA assessments of operating fuel cell micro-CHP systems, carried out as part of the ene.field project, confirm the significant decarbonization potential of these systems compared to incumbent technologies (e.g. by more than 30% compared to a condensing gas boiler under certain assumptions), including heat pumps.

- **Efficiency Gains**

Micro-CHP can help reduce energy waste, when prioritised over less efficient, more polluting and costlier thermal conventional power plants and condensing boilers. On average, high-efficiency cogeneration reaches 10 to 30% higher energy savings than the separate production of heat and electricity, allowing the unlock of considerable energy reserves. In addition, according to CHP manufacturers' estimates, cogeneration has the potential to deliver a 20-30 bcm reduction of gas use by 2030, which corresponds to 20% of the REPowerEU objective.

- **Energy cost reduction**

In the context of the unprecedented energy crisis Europe is facing, mitigating the energy consumer cost will be critical. Fuel cell micro-CHP efficiency benefits translate in lower energy cost for end consumers. The energy cost savings of micro-CHP are achieved given the added value

[9] Artelys. (2020). *Towards an efficient, integrated and cost-effective net-zero energy system in 2050 - The Role of Cogeneration.* Retrieved from https://www.artelys.com/wp-content/uploads/2020/11/Artelys-Presentation-Key-Findings-Study-Commissioned-by-CE-final-1.pdf

of on-site electricity production and self-consumption, which can vary depending on the ratio of between retail electricity and gas prices. In the current volatile markets environment, it might be difficult to predict the short-term cost-effectiveness of micro-CHP systems. Yet, as long as subsidy schemes apply fairly to all types of end-users, micro-CHP should have a pay-back time below 10 years and offer lower energy cost compared to the operating costs of a condensing boiler and electricity from the grid.

Chapter 3: Benefits brought by FC micro-CHP deployment in Germany

Chapter 2 has shed light on the range of system-wide benefits a large-scale rollout of FC mCHP units can bring about in the context of the energy and climate transition. Nevertheless, to deliver on the promises of sustainable, affordable, and secure energy supply, FC mCHP units must be installed against the backdrop of an enabling regulatory and business environment. Germany, in this regard, has proven the ideal early adopter to set the basis for FC mCHP mass market uptake. The country has hosted two large-scale demonstration projects aiming at mCHP commercialization and sent out encouraging signs for the establishment of a competitive FC mCHP market. Building on the milestones achieved in the context of the EU-funded projects ene.field and PACE, Germany is well equipped to be the hub of FC mCHP mass-market commercialization across Europe by further extending its dedicated support schemes (i.e subsidy scheme for FC mCHP - KfW 433), its developed manufacturer, and installer base, and consolidating partnerships between industry, policymakers, and customers.

ene.field: Germany ready to embrace the benefits of the pilot

Germany was a target country for the **ene.field** [10]project running from 2012 to 2017, a European demonstration project to test the benefits of fuel cell micro-CHP installations in more than 1000 households across Europe. The five-year project, co-funded by the Fuel Cells and Hydrogen Joint Undertaking used modern fuel cell technology to produce heat and electricity in households and empower them in their electricity and heat choices. Germany's market proved very receptive to Fc mCHP deployment: the majority of the units deployed were installed therein due to the supporting financial schemes and favorable spark spread (difference between electricity price and gas price), which made FC mCHP more beneficial.

In the context of ene.field, a study[11] carried out by energy consultancy Element on whole-system performance benefits has shown that installing systems producing heat and electricity through FC mCHP in households can immediately decrease infrastructure CAPEX costs (including in

[10] More details on the project can be found on the dedicated *website.*
[11] See footnote 4

generation, transmission and distribution) as well as OPEX costs in the long run, compared to a system where heat is produced through heat pumps and electricity through conventional generation. On average, Element Energy finds the total (gross) benefits with FC mCHP are around €6000 - €7300/kW per year, with greater benefits in case of large uptake of FC mCHP installations and smart grid technologies.

Even in a low uptake scenario, the study highlights how the German distribution network could be positively impacted by FC mCHP installations. By 2030, Germany could achieve €2500/kW savings on its distribution network costs, most of which by deferring voltage-driven investment in LV distribution networks.

Moreover, the analysis finds that positive effects stemming from the rollout of micro-CHP are not limited to improved overall system efficiency, but also include considerable carbon savings. The magnitude of the carbon saving per kW installed micro-CHP in Europe is estimated between 370 – 1100 kg CO2 per year. In the short and medium term, at least when the use of conventional coal/gas/oil-fired plants is still dominant, the impact of micro-CHP in reducing carbon emissions is expected to be relatively significant.

Being the country with the largest FC mCHP base, the rollout of emission reduction benefits could be quite significant for Germany, especially until 2040, when enlarging the FC mCHP fleet would displace highly polluting energy sources. In a high uptake, FC mCHP scenario, the carbon emission reduction for Germany is the highest in the EU by 2030, with more than 7 million tons of CO2 saved compared to no FC mCHP uptake. Moreover, as evidenced by the ene.field public report, compared to alternatives, FC micro-CHP gains are not limited to curbing CO2 emissions, as units generally lead to lower air pollutant emissions compared to alternative systems.

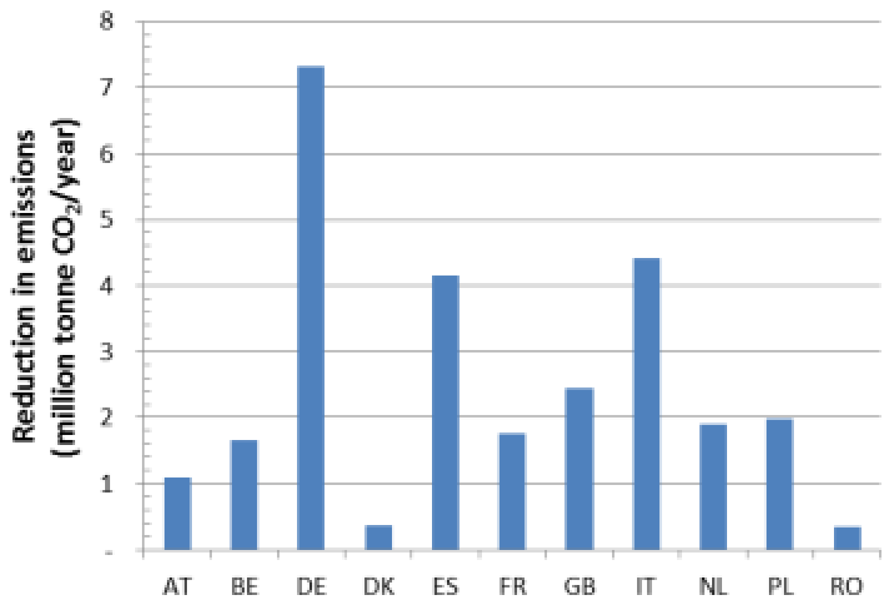


Figure 2 Contribution of micro-CHP in reducing carbon emissions by 2030 (maximum uptake scenario) [12]

PACE: concrete benefits and customer satisfaction with FC mCHP

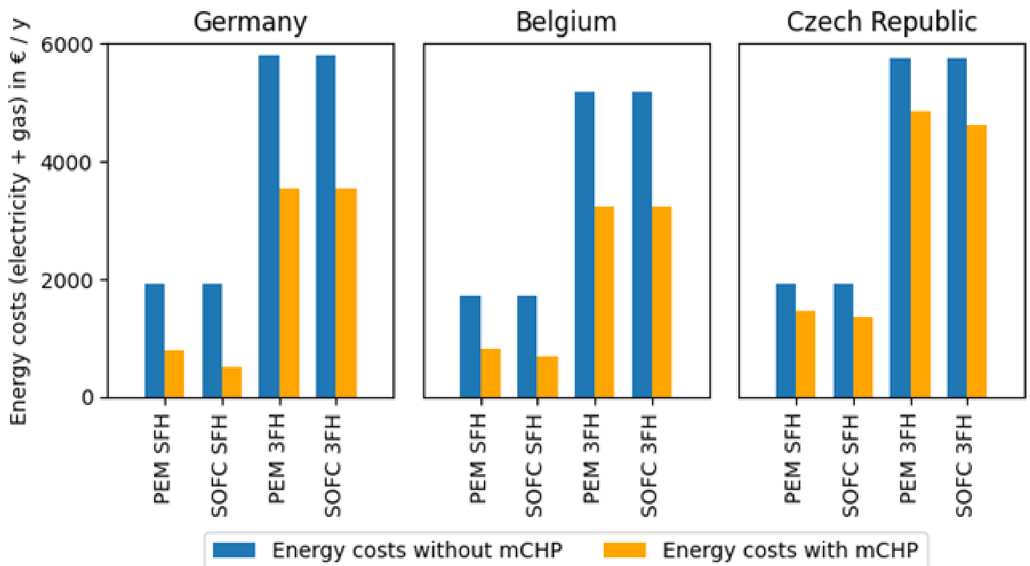
Building on the field trial conducted within the bounds of ene.field, starting from 2018, the EU PACE project[13] contributed to advancing the build-up of FC mCHP capacity throughout Europe, by deploying more than 2,800 next-generation Fuel Cell micro-Cogeneration units in 10 European countries by 2022. Germany was again targeted as a field trial for the deployment of FC mCHP unit and recorded the majority of unit installations

Based on the analysis of individual installations performance, researchers from the Technical University of Denmark have estimated[14] the customer benefits of displacing alternative systems producing heat and electricity with FC mCHP installations. As a result, the analysis shows that mCHP-based replacements unlock potential benefits on three axes: cost savings, primary energy

[12] The graph was extracted from:
Pudjianto, D. (2017). Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System. Imperial College London. Retrieved from http://enefield.eu/wp-content/uploads/2017/10/WP-5.4-Impact-of-widespread-deployment-of-fuel-cell-mCHP-041017-Final_.pdf

[13] For further details on PACE see the dedicated section.
[14] Udbye, E. N., & Prag, C. (2022). Cost and consumption savings in properties with PACE FC mCHP. PACE Project.

savings and CO2 savings. A crucial finding from the performance assessment is that with rising electricity prices, greater financial savings are unlocked. Therefore, higher electricity prices increase customer convenience to switch to FC mCHP applications, a critical consideration considering the seamless electricity price rally in Germany.



A dedicated report on customer attitudes to fuel cell micro-CHP deployment within PACE has provided clearer insights into the success of the German case. Asked to share their feedback on the operational performance of mCHP units, German customers, who represented 46% of the sample, were very participative. The majority of respondents confirmed to have met all their electricity and heat needs through their FC mCHP units, reaffirming their reliability. Moreover, the overwhelming majority recorded a decrease in total energy consumption coupled with decreased energy costs. On top of that, the majority of respondents also confirmed a decrease in CO2 emissions. In sum, PACE confirms that customers were, on the whole, very satisfied with the performance and features of their FC mCHP unit. The environmental impact, comfort, and warmth, design, and generation of electricity were considered the most liked features.

Conclusions

On balance, Germany is committed to ambitious target-setting when it comes to the climate and policy agenda, and the current policy course contemplates the possibility of far-reaching and system-wide changes in the energy field. Germany's ambition to decarbonize and focalize energy-efficient solutions creates an ideal breeding ground for future-proof solutions such as FC mCHP applications, both in terms of mass-market development and political acceptability.

Besides general consideration, the ground reality in Germany suggests that the country is well equipped to evolve into the hub of FC mCHP in the forthcoming years. First, both the ene.field and PIACE field trials of FC mCHP applications in Germany were met with success by both customers and manufacturers. Admittedly, manufacturers acknowledged German customers' responsiveness tow energy-saving solutions, while customers could witness first-hand the plethora of cost and environmental advantages concretely delivered by FC mCHP units.

Furthermore, FC mCHP units are value-added in terms of power system decentralization, and can thus help release pressure from the electric grid. This feature makes such applications extremely serviceable in lowering the risks of resource adequacy, which the current analysis has shown to be a concrete risk for Germany's generation capacity by 2030.

7.2 FC mCHP in the context of Italy's energy and climate agenda

Executive summary

The policy briefing at hand aims to assess how the Italian energy policy renewed ambitions fare with the objective of extending the country's fuel cell micro combined heat and power fleet (FC mCHP). It does so by disentangling the overarching the Italian energy policy architecture along selected policy dimensions, based on high-level national and European target-setting.

Along these premises, **Chapter 1** enucleates the policy dimensions which will determine the opportunities and the costs for a sustained roll-out of mCHP installations in the next years.

Given the unprecedented energy crisis, security of supply and energy affordability have become critical for the Italian economy and its citizens. These compounded crises pose a greater dilemma, as their solution must be balanced out with the need to persist with overall system decarbonization.

Against this complex backdrop, **Chapter 2** will provide an overview of the system-wide benefits brought by FC mCHP applications. FC

Chapter 3 will then be dedicated to highlighting how FC mCHP applications are uniquely placed to contribute to Italy's energy, climate, and competitiveness objectives.

Decarbonisation target

Despite the entry into force of the EU Climate Law, which puts the European Union to reduce its GHG emissions by 55% by 2030 and reach climate neutrality by 2050, Italy belongs to the niche of EU countries that have not transposed the emissions reduction objective into national legislation. Therewith, Italy's integrated national energy and climate plan (NECP) submitted to the European Commission in accordance with EU Regulation 2018/1999 is the factual reference framework enucleating the targets and measures that define the country's contribution to achieving European energy transition and climate targets. Whilst an overhaul of the current NECP looms within the pages of the National Recovery and Resilience Plan (NRRP), Italy's national legislative framework on climate and energy is not yet commensurate with European ambitions. Consequently, Italy's current commitment to system-wide decarbonization as set out in the NECP is curbing GHG emissions by at least 43% by 2030 compared to 2005 levels in ETS sectors (energy industries, energy-intensive industries, and aviation) and 30% by 2030 for non-ETS sectors, such as transport, residential, services, non-ETS industry, agriculture, and waste.

RES Penetration in Heating

The latest Italian NECP (p. 68) sets the goal of reaching 30% RES use in final consumption by 2030. In line with the approach taken by the 2018 recast Renewable Energy Directive (RED II), high-level national strategies express RES contribution toward meeting the overall target through different sectoral sub-targets. The NECP states the national commitment to achieve a 33.9% RES share in the heating sector (for both heating and cooling) by 2030. According to the analysis conducted within the last Comprehensive Heating and Cooling Assessment, the mix of technologies for achieving the 2030 RES target in the thermal sector will be distributed as follows: out of the expected 14.8 Mtoe of thermal renewables 7 will come from solid biomass, 5.8 from heat pumps, 0.9 from solar and geothermal combined, 0.5 from heat from renewable district heating and 0.6 from non-district heating derived heat from RES.

RES gases, such as biogas and biomethane are a major component of the strategy for renewables uptake in Italy, given the country's consolidated use of biomethane for agricultural purposes. As evidence thereof, the section on biomethane development of the National Recovery and Resilience Plan sets the objective of improving the efficiency of existing and new biogas and biomethane agricultural production plants to steer greater biomethane reserves for heating and cooling in the residential and industrial sectors. Nevertheless, the Italian NECP hints that given the untapped potential of biomethane supply in Italy, already available biomethane supply will also be needed to meet the biofuels emission quota under RED II, as it is expected to make up for 75% of the total advanced biofuels sold into the market. The issue of competing uses receives greater emphasis in the NECP section outlining the planned policy measures to reach EU targets for RES.

On one hand, no explicit mention is made of using biomethane to decarbonize heating and cooling purposes. The same sections explicitly to alternative thermal renewable energy sources.

On the other, the list of measures envisaged for the transport sector overtly includes the uptake of biomethane, which is considered vital to reach the EU binding advanced biofuels target. The aforesaid issue of competing uses leads to a fragmented strategic framework for biomethane, whose use will be a bone of contention between the heating and transport sectors until it will be produced on a large scale. The upcoming NECP revision, which will supposedly adjust Italy's climate and energy commitments to the new EU targets, is called to shed light on the most effective use of biomethane. Within this mixed picture, on 8 August 2022, Italy obtained the European Commission's approval for a €3.5 billion support scheme under the Recovery and Resilience Facility (RFF) to support the construction and the operation of new or converted biomethane production plants. The scheme will support the production of sustainable biomethane to be injected into the national gas grid for use in the transport and heating sectors.

Use of Hydrogen in buildings

Italy's policy framework for hydrogen (H2) is not fully consolidated, since Italy lacks a de -facto long-term national strategy for hydrogen. Pending its publication awaited for 2023, Italy has released some preliminary guidelines at the end of 2021, which anticipate the country's vision for H2 in the path toward decarbonization. The document reads Italy's ambition to use available green hydrogen to decarbonize long-range transportation, clean up hard-to-abate industrial uses, and green the gas grid until 2030. The use of hydrogen in the heating sector is planned at the other end of the energy transition: by 2050, the guidelines report, H2 can be used in boilers as an alternative to heat pumps and biomethane-based heating systems.

Energy Efficiency

As part of its commitments shouldered within the framework of the NECP, Italy intends to pursue the objective of reducing primary energy consumption and final energy consumption by 43% (132.0 Mtoe saved) and 39% (103.8 Mtoe) respectively, compared to the 2007 PRIMES scenario. The NECP also estimates the distribution of expected contributions by sector, based on their energy efficiency potential (**Figure 1)**.

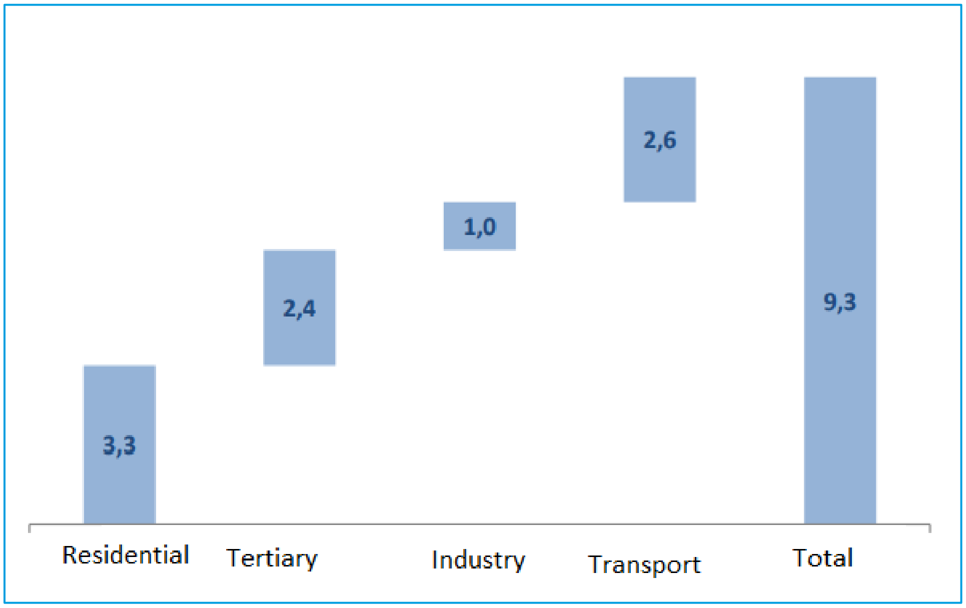


Figure 3 Distribution of the savings forming the subject of the 2030 target by economic sector (Mtoe), Italy NECP

Therefore, according to the assessments performed within the NECP, Italy aims by 2030 to achieve an annual energy saving from the renovation of buildings of 5.7 Mtoe, 3.3 Mtoe of which will derive from the residential sector (35% of the cumulative annual energy savings) and 2.4 Mtoe from the tertiary sector (public and private), which amount to nearly 26% of the total annual savings.

Adequacy Gap in Italy

As noted by the European Commission, the integration of more intermittent renewable energy is changing the structure of power generation capacity. Undeniably driving forward the decarbonization of the electrical system, the transition to renewable-based generation can nonetheless pose great risks to the security of supply. The 2021 European Resource Adequacy Assessment released [15] by ENTSO-E estimates, the adequacy risks expected for EU Countries in 2025 and 2030, with or without capacity mechanisms (CMs). Across the peninsula, the 2025 reference scenario for Italy shows minimal adequacy risks, due to the low average value for loss of load expectation – the value is a reliability indicator in the electricity market as it represents the expected number of hours per year that a country's electricity production park cannot meet its demand. On the other hand, Italian islands are expected to face considerable adequacy risks on account of their lack of interconnectedness to the mainland. On top of that, ENTSO-E attributes adequacy concerns to the planned coal phase-out in Sardinia. On the contrary, the outlook for 2030 is promising, as Italy is expected to mitigate the scarcity risk with planned grid development and new replacement capacity.

According to the ENTSO-E analysis, national estimates scenarios can considerably vary including in Italy if an economic viability assessment is factored in, which considers capacity exit due to non-viability and potentially decreasing thermal capacity. Under this assumption, adequacy risks appear all around Europe as of 2025, with Italy required to introduce capacity mechanisms to cope with system inadequacy and especially as a means to mitigate scarcity risk in the islands.

Chapter 2: General benefits of micro–CHP Applications

The large-scale deployment of FC mCHP installations goes together with the accomplishment of national and EU-wide climate and energy objectives. Seizing the untapped potential of mCHP installations can contribute to delivering a secure, sustainable and competitive energy transition for European consumers.

Decentralization of power and heat supply

Micro-CHP ensures on-site electricity production and self-consumption, empowering citizens to generate their own efficient, reliable, and affordable clean heat on the spot. For this reason, all CHP users, rely less on electricity drawn from the grid avoiding grid costs such as those related to energy transportation infrastructure both at the end-user and system level. Looking at the numbers, the on-site nature of FC micro-CHP production enables to avoid transmission and

[15] The report is available here: *ERAA | European Resource Adequacy Assessment (ERAA) (entsoe.eu)*

distribution grid losses (4%-12%). According to the flagship EU project *ene.field* [16] estimates[17], installing a micro-CHP could reduce power grid costs by 2500 EUR per unit, while helping to reduce peak demand in winter resulting from the installation of heat pumps. Prospectively, researchers from the Imperial College in London have calculated that under a high uptake scenario, micro-CHP can save European consumers € 62 billion in avoided grid costs, which is equivalent to 28% of projected additional costs for 2030.

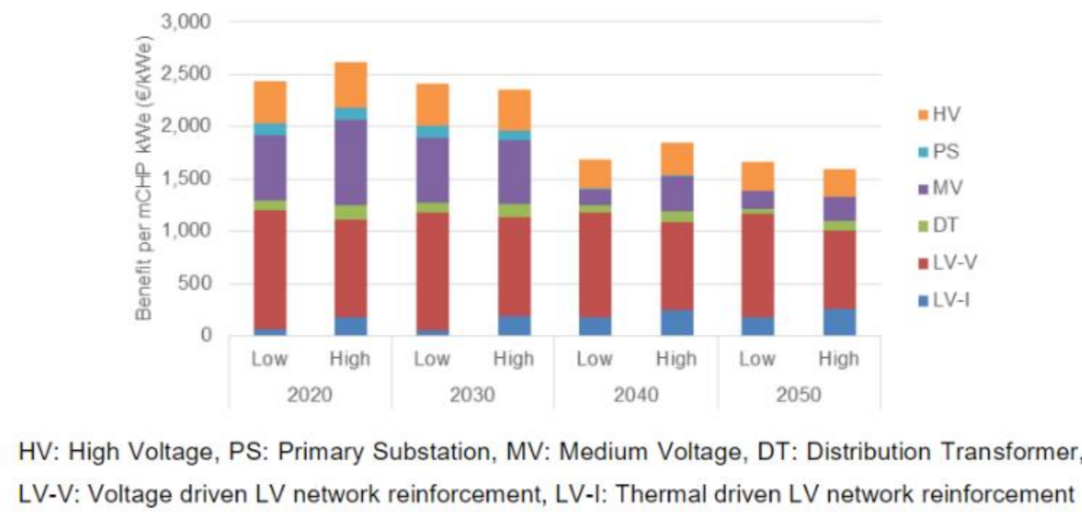


Figure 4 Estimated average value of micro-CHP in reducing distribution network cost in Europe in different scenarios

Alongside reduced user costs, the roll-out of mCHP installations mitigates network overload risks, as both electricity and heat are produced locally.

Higher system resiliency supporting the buildout of renewable energy

Micro-CHP can participate in grid-balancing and help support the intermittent generation of electricity from renewables, by quickly ramping up and down electricity production. For example, a micro-CHP unit can efficiently generate electricity at times of need, both tackling peak heat demand periods when higher generation capacity is needed, or the RES generation

[16] ''Ravn Nielsen, ., & Prag, . (2017). *Learning points from demonstration of 1000 fuel cell based micro-CHP units.* Technical University of Denmark. Retrieved from http://enefield.eu/wp-content/uploads/2017/10/ene.field-Summary-Report.pdf

[17] Pudjianto, D. (2017). Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System. Imperial College London. Retrieved from http://enefield.eu/wp-content/uploads/2017/10/WP-5.4-Impact-of-widespread-deployment-of-fuel-cell-mCHP-041017-Final_.pdf

output fails to meet demand. Among other features, micro-CHP units can also provide a local peaking capacity (back-up) and become an alternative to the conventional boiler in a smart home environment where the electricity and heat demand can be managed more efficiently.

Compatibility with smart grids

The FC micro-CHP technology is well suited for integration into smart grids, enabling to fully harness the benefits of grids digitalization while offering grid-balancing and peak shaving services. In this connection, micro-CHP units can be remotely controlled and can adjust to external heat and power demands at seconds' notice when at operating temperature.

Advancement of energy system Integration

The rollout of micro-CHP units can prove a key system integration solution, linking electricity, heat and gas systems at local level in the most efficient way possible. Micro-CHP applications are well suited to complement the direct electrification of heat, as they help supply heat and power at times of peak heat demand. A 2021 study[18] released by consulting company Artelys shows that synergies between direct electrification (with heat pumps) and efficient indirect electrification (with cogeneration) are key to maintaining system stability and lower overall system costs in a net zero energy system.

Decarbonisation and environmental benefits

In the context of the scaling up of RES-based CHP (running on H2 or other renewable gases), micro-CHP will be increasingly associated with significant emissions reductions or even negative emissions, when coupled with CCUS technologies. As proof of that, LCA assessments of operating fuel cell micro-CHP systems, carried out as part of the ene.field project, confirm the significant decarbonization potential of these systems compared to incumbent technologies (e.g. by more than 30% compared to a condensing gas boiler under certain assumptions), including heat pumps.

Efficiency Gains

Micro-CHP can help reduce energy waste, when prioritised over less efficient, more polluting, and costlier thermal conventional power plants and condensing boilers. On average, high-

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[18] Artelys. (2020). *Towards an efficient, integrated and cost-effective net-zero energy system in 2050 - The Role of Cogeneration.* Retrieved from https://www.artelys.com/wp-content/uploads/2020/11/Artelys-Presentation-Key-Findings-Study-Commissioned-by-CE-final-1.pdf

efficiency cogeneration reaches 10 to 30% higher energy savings than the separate production of heat and electricity, allowing the unlocking of considerable energy reserves. In addition, according to CHP manufacturers' estimates, cogeneration has the potential to deliver a 20-30 bcm reduction of gas use by 2030, which corresponds to 20% of the REPowerEU objective.

Energy cost reduction

In the context of the unprecedented energy crisis Europe is facing, mitigating the energy costS for consumers will be critical. Fuel cell micro-CHP efficiency benefits translate in lower energy cost for end consumers. The energy cost savings of micro-CHP are achieved given the added value of on-site electricity production and self-consumption, which can vary depending on the ratio of between retail electricity and gas prices. In the current volatile markets environment, it might be difficult to predict the short-term cost-effectiveness of micro-CHP systems. Yet, as long as subsidy schemes apply fairly to all types of end-users, micro-CHP should have a pay-back time below 10 years and offer lower energy cost compared to the operating costs of a condensing boiler and electricity from the grid.

Chapter 3: Benefits brought by FC micro-CHP deployment in Italy

Chapter 2 has shed light on the range of system-wide benefits a large-scale rollout of FC mCHP units can bring about in the context of the energy and climate transition. Nevertheless, to deliver on the promises of sustainable, affordable, and secure energy supply, FC mCHP units must be installed against the backdrop of an enabling regulatory and business environment. The entrepreneurial context for FC micro-CHP in Italy is two-sided. On the one hand, administrative and regulatory barriers still hamper the large-scale adoption of FC mCHP solutions. The *ene.field* project takes stock of the lengthy bureaucratic procedures for the installation and authorization process of FC mCHP units, also mentioning grid connection delays among the greatest hindrances.[19] In spite of that, Italy is well-placed to become a starting market for FC mCHP applications, as the country offers a host of enabling conditions for mass-market uptake. Thanks to the presence of some national industrial frontrunners such as AB Energy, Baker Huges, Turboden, SOLIDPower, and others - cogeneration players recognized

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COGEN Europe. (2017). *Fuel Cell micro-CHP in the Context of EU's Energy Transition - Policy Analysis & Recommendations.* Ene.field Project. Retrieved from http://enefield.eu/wp-content/uploads/2018/01/2017_11_07_FINAL-DRAFT_Fuel-Cell-micro-CHP-in-the-Context-of-EU-Energy Transition-1.pdf worldwide for their capacity for innovation and technological design - Italy is a key hub of cogeneration know-how in Europe. Alongside the rooting of CHP in the Italian industrial landscape, the regulatory environment remains supportive of CHP applications. At the time of writing, the Italian Government offers incentives and tax advantages for high-energy efficiency CHP plants, among which:

reduced excise duty regime for gas used in cogeneration units

a targeted support scheme for energy savings made with cogeneration units, through the so-called *white certificates (*i.e energy efficiency certificate*s)*, which could potentially be applied to energy savings achieved through FC mCHP units.

Moreover, under certain conditions[20], electricity produced by HE CHP units is given priority in dispatching power to the network

A 20-year comprehensive overhauled tariff for cogeneration plants using renewable sources.

On top of that, Italian customers have had a positive first-hand experience with FC mCHP applications, considering that from 2012 Italy has been among the targeted countries of two EU-branded field trial projects - ene. field and PACE - aimed at advancing the build-up of FC mCHP capacity throughout Europe.

Ene.field

Italy was selected as a target country for the **ene.field** project running from 2012 to 2017, a European demonstration project to test the benefits of fuel cell micro-CHP installations in more than 1000 households across Europe. The five-year project, co-funded by the Fuel Cells and Hydrogen Joint Undertaking used modern fuel cell technology to produce heat and electricity in households and empower them in their electricity and heat choices. Fuel cell mCHP units from **SOLIDpower**, **Elcore**, **Hexiz** and **RBZ** were made available for field trials over the duration of the project.

In the context of **ene.field**, a study[21] carried out by energy consultancy Element on whole-system performance benefits has shown that installing systems producing heat and electricity

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[21] "Ravn Nielsen, ., & Prag, . (2017). *Learning points from demonstration of 1000 fuel cell based micro-CHP units.* Technical University of Denmark. Retrieved from http://enefield.eu/wp-content/uploads/2017/10/ene.field-Summary-Report.pdf

through FC mCHP in households can immediately decrease infrastructure CAPEX costs (including in generation, transmission and distribution) as well as OPEX costs in the long run, compared to a system where heat is produced through heat pumps and electricity through conventional generation. On average, Element Energy finds the total (gross) benefits with FC mCHP are around €6000 - €7300/kW per year, with greater benefits in case of large uptake of FC mCHP installations and smart grid technologies.

Even in a low uptake scenario of FC mCHP installations, the study estimates considerable benefits for the Italian distribution network. **Figure 3** shows that by 2030, Italy could achieve nearly €2600/kW savings on its distribution network costs, most of which by deferring voltage-driven investment in LV distribution networks. Other visible savings would be obtained at the level of Medium Voltage (MV) feeders as the micro-CHP can release some capacity and defer the future network investment requirement due to load growth.

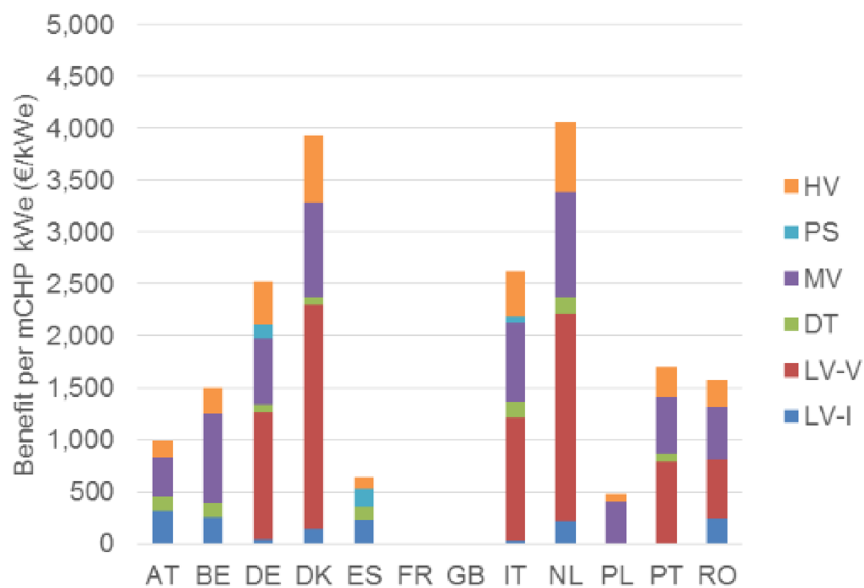

Figure 5 Estimated value of micro-CHP in reducing distribution network cost in Europe [2020: low-uptake scenario]

PACE

Building on the field trial conducted within the bounds of ene.field, starting from 2018, the EU PACE project[22] contributed to advancing the build-up of FC mCHP capacity throughout Europe, by deploying more than 2,800 next-generation Fuel Cell micro-Cogeneration units in 10 European countries by 2022. Italy was targeted as a field trial for the deployment of FC mCHP unit and has recorded 53 confirmed installations[23].

[22] For further details on PACE see the dedicated section.

[23] More information on Italy is retrievable on the dedicated section of the *PACE* website.

PACE Policy Analysis and Recommendations on fuel cell micro-cogeneration in the Netherlands

Representing the Fuel Cell micro-Cogeneration (FC micro-CHP) sector, the PACE project welcomes the Netherlands' strategies and plans to achieve net zero by 2050 according to the European Union's strategy and initiatives under the European Green Deal. Moreover, the Netherlands wants to reduce its greenhouse gas emissions by 49% by 2030, compared to 1990 levels, and a 95% reduction by 2050. These goals are laid down in the Climate Act on May 28, 2019.

Fuel Cell micro-Cogeneration is a highly efficient approach to providing on-site electricity and heat suitable for a small business or house from a single fuel. First, the fuel is transformed into hydrogen and the fuel cell uses this hydrogen to generate electricity and heat. Fuel Cell micro-Cogeneration units are designed to meet the electrical, space heating and hot water demands of a building. More information on PACE Project can be found *HERE*.

This briefing paper makes policy recommendations to support the widespread deployment of fuel cell micro-cogeneration systems, while providing a review of policy frameworks for the four identified and prioritised targeted countries expected to impact the uptake of the technology in the coming decade. This paper highlights the benefits of fuel cell micro-cogeneration in relation to the Netherlands' energy and climate objectives to achieve net zero economy by 2050.

In December 2019, the European Commission presented the European Green Deal, a growth strategy to transition the EU economy to a sustainable economic model. The overarching objectives of the EU Green Deal are to reduce greenhouse gas emissions in Europe by 55% by 2030 and for the EU to become the first climate neutral continent by 2050, resulting in a cleaner environment, more affordable energy, new jobs and better overall quality of life. In addition, the EU's binding climate and energy legislation requires Member States to adopt national energy and climate plans (NECPs) to cover the 2021-2030 period.

Given the ambitious target in decarbonising the energy, reducing carbon emissions and improving the efficiency of the energy system can be effectively achieved due to wide deployment of micro-CHP. According to the study done by the ene.field EU project on "*Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System*", the magnitude of the carbon saving per kW installed micro-CHP in Europe is estimated between 370 – 1100 kg CO2 per year. In the short and medium term, at least when the use of conventional coal/gas/oil-fired plant is still

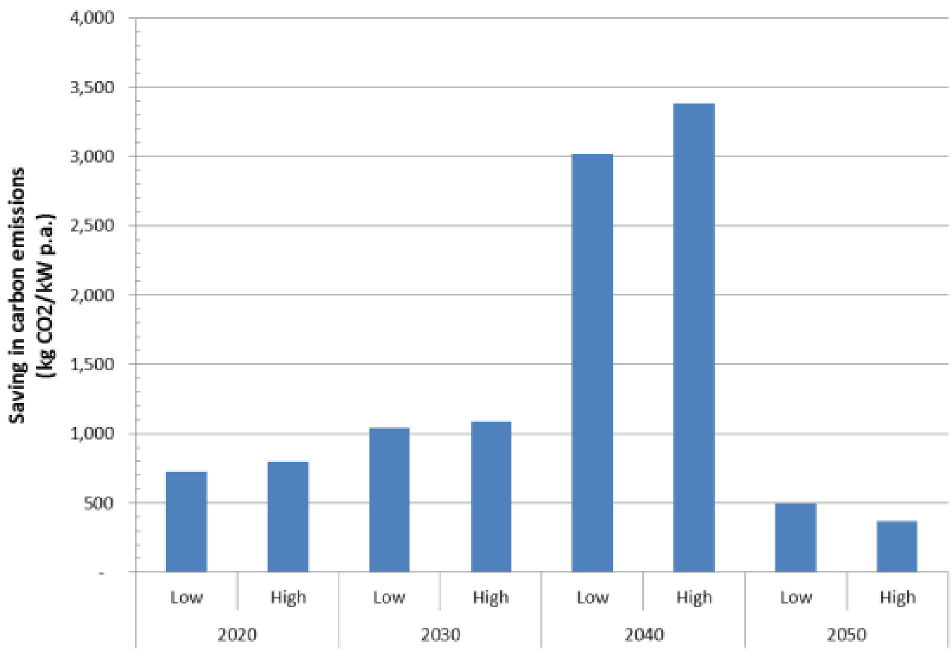

Figure 6. Contribution of micro-CHP in reducing carbon emissions (source: *ene.field report*)

dominant, the impact of micro-CHP in reducing carbon emissions is expected to be relatively significant. In the long term, when the supply of electricity is mainly from low-carbon generation sources, the use of fuels from sustainable and low-carbon sources will be needed for micro-CHP. The results are shown in Figure 1.

Seasonal generation -demand mismatches, caused by winter peaks from heat electrification and the variability of solar PV and wind, can also be better managed together with fuel cell deployment. These peaks should be converted and stored in Hydrogen and used in fuel cells during night- and winter time. Energy profiling, Virtual Power Plant and smart grid opportunities can help with grid balancing.

Energy and climate policy framework in the Netherlands

The Climate Plan, the National Energy and Climate Plan (NECP) and the National Climate Agreement contain the policy and measures to achieve thew Netherlands' climate goals. In October 2020, the European Commission published an assessment for each NECP. According to the European Parliament analysis on *Climate action in the Netherlands*, the Netherlands accounts for 5.2 % of total EU greenhouse gas (GHG) emissions with the energy industries accounted for the largest share of the Netherlands' GHG emissions. Moreover, the Netherlands increased its renewable energy share of gross final energy consumption by 6.3% between 2005 and 2019. To meet the 2030 target, the renewable energy share of gross energy consumption must rise from 8.8 % to 27 % in just over a decade. Dutch government has set objectives for the minimum share of renewable energy in different sectors: 13 % in heating and cooling, 32 % in transport and 73 % in the electricity sector, where solar power and offshore and onshore wind farms are among the technologies to grow. The Netherlands relays on natural gas but is planning to end most natural gas extraction from the Groningen gas field by 2022. This closure will take place in stages, with a complete halt between mid-2025 and mid-2028.

Buildings

In the building sector, the Netherlands is aiming for emissions of around 15.2 to 17.7 MtCO2e by 2030, a reduction from 24.4 MtCO2e in 2018. By 2030, the CO2 intensity of the heat supplied to homes must have been reduced by 70% in comparison with current central-heating boilers. By 2050, the heat supplied must be fully sustainable. This is to be achieved mainly through changes to heating sources with the phasing-out of natural gas, starting with new buildings. Adjustments will be made to energy taxation, with higher taxes on natural gas and lower taxes on electricity. Among other measures, the country intends to develop new financial instruments to address sustainability in the built environment. Currently, Dutch natural gas is the primary source of energy for heating homes and buildings. Dutch government, among other things, is planning to meet the remaining demand for heat via local heat generation (using heat pumps and solar boilers, among others), district heating (based on residual heat or geothermal energy), or biogas.

According to the European Commission, in EU households, heating and hot water alone account for 79% of total final energy use (192.5Mtoe). Approximately 75% of heating and cooling is still generated from fossil fuels while only 22% is generated from renewable energy. In the Netherlands, the aim is that 1.5 million homes will have been made natural-gas-free by 2030. Therefore, to achieve all of the objectives above the Netherlands will need to: 1) rely on a diverse mix of renewable and efficient solutions; 2) promote the efficient use of energy in buildings via heat pumps, cogeneration and district heating; and 3) foster system resiliency and flexibility by supporting the highly efficient and low-carbon dispatchable power solutions, including fuel cell micro-CHP, which can run on increasingly renewable fuels, as renewable gases and hydrogen. Micro-CHP solutions are now available on the market and can be installed in up to 25% of EU's buildings[24], as part of a cost-effective pathway to a carbon neutral EU by 2050. Moreover, electrically led fuel cells can support grid infrastructure and mitigate outages caused by

[24] *https://www.artelys.com/wp-content/uploads/2020/11/Artelys-Presentation-Key-Findings-Study-Commissioned-by-CE-final-1.pdf*

the increased power demands from heat pumps, electric vehicles and other electrification measures. Covering the baseload of housing stock and business operations (continuously) decentralises power consumption. As buildings electrify, demand response, flexible generation and energy efficiency will play an even more important role in integrating higher shares of renewable energy at lowest cost for consumers. In the Netherlands, according to its Heating & Cooling Assessment, the purchased heat and self-generated CHP heat primarily consist of heat from district heating, with short-term trends highly dependent on the weather during the heating season.

Dutch government is promoting a 1.5% increase in energy savings per year in order to cut CO2 emissions. Homeowners can get loans or grants to make their homes energy efficient. It is noticeable that to efficiently use the primary source of energy, namely natural gas, in buildings, the Netherlands needs to increase its energy efficiency also resulting in lower operating costs for the users. Micro-CHP systems help to achieve significant primary energy efficiency and transform consumers into energy 'prosumers' (i.e. producers and consumers), putting them at the core of future energy systems. Therefore, to fully reap the benefits of micro-CHP, the Netherlands should foster all renewable energy sources and their efficient use for the affordable and secure supply of heat and power to buildings.

Hydrogen

In its NECP and National Strategy to achieve the 2030 GHG emission reduction targets, the Netherlands is committed to launch a hydrogen programme, which would support the ambition to have an installed electrolyser capacity of 3-4 GW in 2030. The Dutch NECP does not provide hydrogen use targets per sector nor specific hydrogen-related measures, but the Government is committed to cooperate on policy instruments and practical measures with other European countries. Furthermore, the Dutch government has recently published a Hydrogen Vision, which describes the role for hydrogen in the future energy system and the measures that will be taken to promote hydrogen development[25]. Hydrogen can be also successfully used to increase a flexibility to power grid by fuel cell micro-CHP in residential applications, which helps to reduce CO2 emissions. Flexible solutions to decarbonise heat in buildings, including fuel cells, are hydrogen-ready and can provide 100% renewable energy of green gas in the grid. Fuel Cell technology is designed with this transition in mind and using it will further accelerate future gains in energy efficiency and carbon reduction. Moreover, residential fuel cells have the added benefit of generating electricity when and where needed, addressing the challenges of direct electrification and increasing shares of variable renewable sources. The evidence shows that seasonal generation/demand mismatches, caused by winter peaks from heat electrification and the variability of solar PV and wind, can be better managed together with fuel cell deployment in buildings. In addition, residential fuel cells can support grid infrastructure and mitigate outages caused by the increased power

[25] *Opportunities for Hydrogen Energy Technologies Considering the National Energy & Climate Plans*, FCH JU

demands from heat pumps, electric vehicles and other electrification measures. Covering the baseload of housing stock and business operations (continuously) decentralises power consumption. Making it local, efficient and flexible.

Support for micro-CHP in the Netherlands

With the increasing role of renewable gas applications in the Netherlands, support is needed for the deployment of new technologies. The sustainable contribution of these technologies should also be fully incorporated in calculation methods such as Energy Performance certificates (EPCs) for homes and buildings. Although we have in the Netherlands several support schemes aiming at improving the overall energy efficiency and acceleration of renewable energy across country, mainly in residential and business sectors, fuel cell micro-CHP are nowhere to find as a technology/solution listed to receive a support. It is not recognised as a solution which can be used for heat generations in buildings, which constitute as one of the priorities for the Netherlands in reducing its CO2 emissions.

In the Netherlands, green funds and green banks can apply for a green certificate – under Green Projects Scheme, which can finance sustainable projects of their customers at a lower interest rate. The scheme is interesting for entrepreneurs who are looking for financing for investments in innovative, sustainable techniques that entail extra costs and risks and are therefore difficult to finance. Individuals can apply for the Energy Saving Loan, under the National Heat Fund, which is an attractive option where you can finance energy-saving investments for your own home. The loan can be given for the HEe boiler or micro-CHP which has a minimum capacity of 0.8 kWe and a maximum of 5 kWe. The volume of funding for each individual beneficiary is between €2,500 and the maximum of €15,000 or €25,000, depending on the term.

Moreover, there is an online tool - *the Energy Subsidy Guide*, which shows you whether you can get a subsidy or loan if you are going to make your house more sustainable. Some municipalities also offer their own loans, as Loan Sustainability Fund in Amsterdam, to support projects aiming at saving energy.

Overall, the policy framework for fuel cell micro-CHP in the Netherlands is not favourable. High-level recognition of the environmental and energy security contribution of fuel cell micro-CHP technologies towards the Netherlands energy transition is key for the successful mass commercialization of these products. The fuel cell sector is dynamic with scope for technology improvement and evolution. According to the Fuel Cells and Hydrogen Joint Undertaking and its *analysis of renewable hydrogen and* *end users in the Netherlands by 2030*, the introduction of 11 520-50 120 micro-CHP units in building is estimated.

Benefits of Fuel Cell micro-Cogeneration

The Fuel Cell micro-Cogeneration can significantly contribute towards the energy and climate objectives to benefit from energy efficiency gains and to deliver higher ambition in terms of both energy efficiency and decarbonisation. In short, we would like to stress the following:

Heating and cooling in buildings shall consider fuel cell micro-CHP as a key solution

With total efficiencies of more than 90%, including electrical efficiencies of up to 60% (for SOFC fuel cells) and up to 38% (for PEM fuel cells), this technology can achieve significant energy savings and CO2 emission reductions. This “fuel flexible” technology will be progressively fuelled by renewable energy sources, such as hydrogen and renewable gas.

The efficient use of hydrogen is promoted via micro-CHP

In the long term, biogas or hydrogen at volume could provide an alternative renewable gas to natural gas, which makes a case for the fuel cell micro-CHP more appealing.

The benefits of fuel cell micro-CHP for power grids should be fully recognised

By generating heat and electricity near the point of consumption, Fuel Cell micro-Cogeneration relieves the stress on the electricity grid during peak demand (e.g. for powering heat pumps and charging electric vehicles). They play an important role in generating high efficiency electricity at times of insufficient intermittent renewables. This will also help supply flexible electricity to support the grids and reduce the overall cost of decarbonising buildings.

Empowers consumers

Fuel cell micro-Cogeneration transforms Europeans into active energy ‘prosumers’ (producer-consumers), creating a decentralised energy system with a reduced carbon footprint and lower energy bills. The most highly efficient fuel cell micro-CHP technologies can be operated according to electricity demand when installed in new low-energy buildings-but are also suitable for existing buildings.

Fosters innovation and high value jobs

Provides new and highly skilled green jobs in Europe, while building on the existing expertise of the heating industry.

Because fuel cell micro-cogeneration attains high efficiencies, it reduces primary energy and results in greenhouse gas (GHG) emission reductions. In addition, the mode of operation of the micro-Cogeneration unit can support the grid integration of variable renewables.

As part of the ene.field EU flagship project, the large scale uptake of micro-CHP has been further analysed in terms of macro-economic and -environmental benefits up to 2050. Comparing two scenarios with or without micro-CHP, installing 1 kW of micro-CHP helps avoid more than 2,000 EUR in the electricity grids (equivalent to **more than EUR 30 bn in avoided grid investments in 2030, assuming the full economic potential is realised**). Decarbonisation benefits range between 500 kg & 3.5 tons CO_2/kW per year between now and 2050, assuming no uptake of renewable gas (which would bring further decarbonisation benefits).

PACE Policy Analysis and Recommendations on fuel cell micro-cogeneration in the UK

Representing the Fuel Cell micro-Cogeneration (FC micro-CHP) sector, the PACE project welcomes the UK's strategies and plans to achieve net zero by 2050 and to accelerate the commercialisation of innovative low-carbon technologies, systems and processes to support the decarbonisation in the buildings, power and industrial sectors, while ensuring affordability and fairness in the transition to a net-zero carbon economy.

Fuel Cell micro-Cogeneration is a highly efficient approach to providing on-site electricity and heat suitable for a small business or house from a single fuel. First, the fuel is transformed into hydrogen and the fuel cell uses this hydrogen to generate electricity and heat. Fuel Cell micro-Cogeneration units are designed to meet the electrical, space heating and hot water demands of a building. More information on PACE Project can be found *HERE*.

This briefing paper makes policy recommendations to support the widespread deployment of fuel cell micro-cogeneration systems, while providing a review of policy frameworks for the four identified and prioritised targeted countries expected to impact the uptake of the technology in the coming decade. This paper highlights the benefits of fuel cell micro-cogeneration in relation to the United Kingdom's energy and climate objectives to achieve net zero economy by 2050.

In 2021 the UK has published a comprehensive Net Zero Strategy which set out the Government's vision for transitioning to a net zero economy, which builds up on the Ten Point Plan for a green industrial revolution announced in 2020 to build back better economy form the impact of COVID-19, support green jobs, and accelerate UK's path to net zero. The Net Zero Strategy includes, among other things, mobilising funds and investments in priority areas, such as industry, hydrogen, buildings and energy storage & flexibility, supporting customers in the energy transition, developing innovative green solutions and decarbonising UK's power system by 2035. Taking into account both its climate and economic objectives, the UK is committed to fostering secure, competitive, and sustainable energy, through specific targets and measures addressing energy efficiency, renewable energy and increased electricity demand.

In the UK, a medium uptake scenario estimates that around 100.000 units of micro-CHP could be installed by 2030. Under this scenario, the decarbonisation impact of micro-CHP could reach 2.5 million tonne CO2/year by 2030. This level of deployment requires an incentive scheme for stationary fuel cells in the form of operational aid and/or capex support to bridge the upfront cost barriers. Given

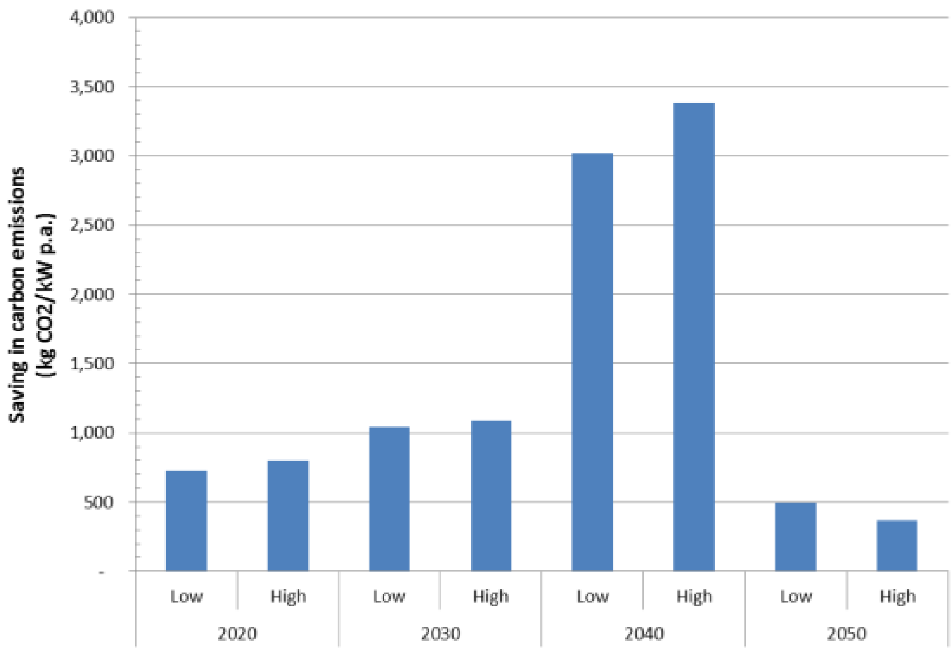

Figure 7. Contribution of micro-CHP in reducing carbon emissions (source: *ene.field report*)

the ambitious target in decarbonising the energy, reducing carbon emissions and improving the efficiency of the energy system can be effectively achieved due to wide deployment of micro-CHP. According to the study done by the ene.field EU project on "*Benefits of Widespread Deployment of Fuel Cell Micro CHP in Securing and Decarbonising the Future European Electricity System*", the magnitude of the carbon saving per kW installed micro-CHP in Europe is estimated between 370 – 1100 kg CO2 per year. In the short and medium term, at least when the use of conventional coal/gas/oil-fired plant is still dominant, the impact of micro-CHP in reducing carbon emissions is expected to be relatively significant. In the long term, when the supply of electricity is mainly from low-carbon generation sources, the use of fuels from sustainable and low-carbon sources will be needed for micro-CHP. The results are shown in Figure 1.

Seasonal generation -demand mismatches, caused by winter peaks from heat electrification and the variability of solar PV and wind, can also be better managed together with fuel cell deployment. These peaks should be converted and stored in Hydrogen and used in fuel cells during night- and winter time. Energy profiling, Virtual Power Plant and smart grid opportunities can help with grid balancing.

Energy and climate policy framework in the UK

Fuel cell micro-CHP can contribute to UK policy objectives in several sectors which have been identified as crucial in achieving net zero by 2050. Policy analysis and recommendations for the large-scale uptake of fuel cell micro-CHP in the UK include the following:

Heat and Buildings Strategy: Households and small businesses will play a vital role in the transition towards a decarbonised society. With heating and cooling in buildings responsible for 36% of carbon emissions in Europe, there is enormous potential to reduce our carbon footprint in the buildings sector, while decreasing energy consumption, carbon emissions and local air pollution. Evidence shows that the UK will need to rely on a diverse mix of renewable and efficient solutions, including hydrogen and fuel cells micro-CHP, to reach net-zero emissions by 2050 at lowest cost for consumers and the energy system. This will help the UK meet the following key objectives already today but also in the long term:

- ✓ Accelerate the decarbonisation of heating in buildings, a hard to abate sector;
- ✓ Reduce the consumption of fossil fuels and maximise the use of renewables, including H2;
- ✓ Fostering clean air and healthier living environments;
- ✓ Support system integration and improve security of supply;
- ✓ Incentivise empowered consumers and self-consumption;
- ✓ Reduce energy costs at system level and for consumers.

Including stationary fuel cell technology within the Heat and Buildings Strategy will help the UK meet all of the objectives above, here and now but also in the future. Electrically led fuel cells can support grid infrastructure and mitigate outages caused by the increased power demands from heat pumps, electric vehicles and other electrification measures. Covering the baseload of housing stock and business operations (continuously) decentralises power consumption. Making it local, efficient and flexible. This means the level of investment considered in the economic assessment for reinforcing or extending grid infrastructure could be drastically reduced.

Hydrogen Strategy: fuel cell technology needs hydrogen, therefore, we welcome the publication of the Hydrogen Strategy. It reaffirms the UK's commitment to the hydrogen sector, highlighting that up to one third of the UK's energy consumption by 2050 could be hydrogen-based. The UK Hydrogen Strategy anticipates that by 2030, less than 70,000 homes could be heated by hydrogen (<1 TWh), but in a positive scenario this could rise to over 3 million homes by 2035 (45 TWh). This can be achieved by providing flexible solutions to decarbonise heat in buildings, including fuel cells, which are hydrogen-ready and can provide 100% renewable energy of green gas in the grid. This is relevant to helping the UK achieve its energy goals. Fuel Cell technology is designed with this transition in mind and using it will further accelerate future gains in energy efficiency and carbon reduction. Fuel cells are hydrogen ready and can meanwhile run on a range of intermediate transitional gas-mixes.

Industrial decarbonisation strategy: this strategy sets out how industry can decarbonise in line with net zero while remaining competitive and without pushing emissions abroad. Although it includes a whole chapter on adopting low-regret technologies and building infrastructure, there is anything specific mentioned regarding CHP and micro-CHP. The strategy put a strong focus on increasing fuel switching to low carbon fuels and the support is given to hydrogen, electrification and bioenergy, but micro-CHP is not specifically included as a technology which can support sectors in decarbonising operations.

Transitioning to a net zero energy system: smart systems and flexibility plan 2021: this plan sets out a vision, analysis and suite of policies to drive a net zero energy system, as smart technologies and flexibility are essential to integrating low carbon power, heat and transport onto the system. Although it includes the need to add additional flexibility in buildings, there is not mention of fuel cells micro-CHP as a possible technology which may contribute to the system. The deployment of fuel cells at scale would introduce new flexible distributed electricity generation capacity into the energy system thus addressing grid security risks at a lower cost. Residential fuel cells have the added benefit of generating electricity when and where needed, addressing the challenges of direct electrification and increasing shares of variable renewable sources. The evidence shows that seasonal generation/demand mismatches, caused by winter peaks from heat electrification and the variability of solar PV and wind, can be better managed together with fuel cell deployment in buildings. In addition, residential fuel cells can support grid infrastructure and mitigate outages caused by the increased power demands from heat pumps, electric vehicles and other electrification measures. Covering the baseload of housing stock and business operations (continuously) decentralises power consumption. Making it local, efficient and flexible.

Support for micro-CHP in the UK

In the UK micro-CHP systems are eligible to receive payments for generating electricity under the Smart Export Guarantee (SEG), which are provided by energy suppliers. The SEG (launched on 1 January 2020) is a government-backed initiative, which requires some electricity suppliers (SEG Licensees) to pay small-scale generators (SEG Generators) for low-carbon electricity which they export back to the National Grid, providing certain criteria are met. Micro-CHP under 50kW can benefit from the SEG, which constitutes as a favourable support, but potentially unambitious, as it is not mainstreamed by the Government. Fuel cell micro-CHP is not recognised in any of main strategies published by the UK and therefore, no incentivise is given to promote this solution among customers. High-level recognition of the environmental and energy security contribution of fuel cell micro-CHP technologies towards the UK energy transition is key for the successful mass commercialization of these products. The fuel cell sector is dynamic with scope for technology improvement and evolution. According to the Fuel Cells and Hydrogen Joint Undertaking and its *analysis of renewable hydrogen and end users in UK by 2030*, the introduction of 34 980-152 170 stationary fuel cells for combined power and heat production is estimated.

Benefits of Fuel Cell micro-Cogeneration

The Fuel Cell micro-Cogeneration can significantly contribute towards the energy and climate objectives to benefit from energy efficiency gains and to deliver higher ambition in terms of both energy efficiency and decarbonisation. In short, we would like to stress the following:

Heating and cooling in buildings shall consider fuel cell micro-CHP as a key solution

With total efficiencies of more than 90%, including electrical efficiencies of up to 60% (for SOFC fuel cells) and up to 38% (for PEM fuel cells), this technology can achieve significant energy savings and $CO2$ emission reductions. This "fuel flexible" technology will be progressively fuelled by renewable energy sources, such as hydrogen and renewable gas.

The efficient use of hydrogen is promoted via micro-CHP

In the long term, biogas or hydrogen at volume could provide an alternative renewable gas to natural gas, which makes a case for the fuel cell micro-CHP more appealing.

The benefits of fuel cell micro-CHP for power grids should be fully recognised

By generating heat and electricity near the point of consumption, Fuel Cell micro-Cogeneration relieves the stress on the electricity grid during peak demand (e.g. for powering heat pumps and charging electric vehicles). They play an important role in generating high efficiency electricity at times of insufficient intermittent renewables. This will also help supply flexible electricity to support the grids and reduce the overall cost of decarbonising buildings.

Empowers consumers

Fuel cell micro-Cogeneration transforms Europeans into active energy ‘prosumers’ (producer-consumers), creating a decentralised energy system with a reduced carbon footprint and lower energy bills. The most highly efficient fuel cell micro-CHP technologies can be operated according to electricity demand when installed in new low-energy buildings-but are also suitable for existing buildings.

Fosters innovation and high value jobs

Provides new and highly skilled green jobs in Europe, while building on the existing expertise of the heating industry.

Because fuel cell micro-cogeneration attains high efficiencies, it reduces primary energy and results in greenhouse gas (GHG) emission reductions. In addition, the mode of operation of the micro-Cogeneration unit can support the grid integration of variable renewables.

As part of the ene.field EU flagship project, the large scale uptake of micro-CHP has been further analysed in terms of macro-economic and -environmental benefits up to 2050. Comparing two scenarios with or without micro-CHP, installing 1 kW of micro-CHP helps avoid more than 2,000 EUR in the electricity grids (equivalent to **more than EUR 30 bn in avoided grid investments in 2030, assuming the full economic potential is realised**). Decarbonisation benefits range between 500 kg & 3.5 tons CO_2/kW per year between now and 2050, assuming no uptake of renewable gas (which would bring further decarbonisation benefits).

8. About the PACE project

PACE is a major EU project unlocking the large-scale European deployment of the state of the art smart energy solution for private homes, Fuel Cell micro-Cogeneration. PACE will see over 2,500 householders across Europe reaping the benefits of this home energy system. The project will enable manufacturers to move towards product industrialisation and will foster market development at the national level by working together with building professionals and the wider energy community. The project uses modern fuel cell technology to produce efficient heat and electricity at home, empowering consumers in their energy choices. PACE project, which stands for "Pathway to a Competitive European Fuel Cell micro-Cogeneration market", is co-funded by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU) and brings together European manufacturers, research institutes and other key energy stakeholders making the products available across 11 European countries. For more information, visit www.pace-energy.eu or contact Mr Janos Vajda via info@pace-energy.eu The PACE partners are

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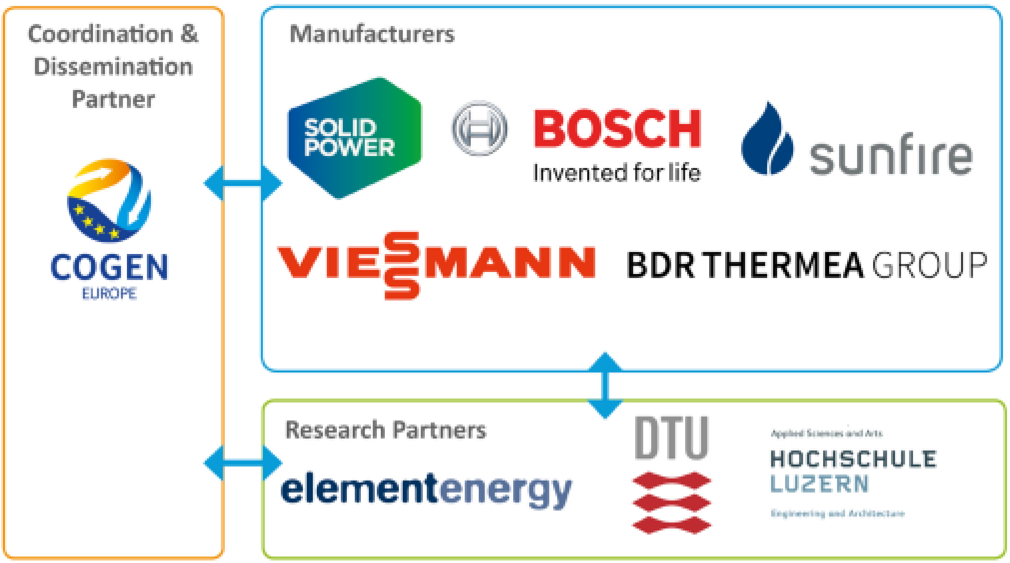

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